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A decision support system for managing results-based financed mega infrastructure programs

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A DECISION SUPPORT SYSTEM FOR MANAGING RESULTS-BASED FINANCED MEGA INFRASTRUCTURE PROGRAMS

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بسم الله الرحمن الرحيم

DEDICATION

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ABSTRACT

International Financial Institutions are exploring solutions that can ensure the effectiveness of funds with respect to the achievement of desired results/outputs. Results-Based finance (RBF) considers this goal through linking desired outputs to the disbursement of funds. This may require borrowers to pre-finance programs and then receive their allocated disbursements after results are achieved, which could form cash flow gaps. The management of this type of programs requires the integration of multiple projects management and finance-based scheduling with the financial requirements of results-based funding mechanisms. For proper management of received funds, this research introduces a framework for the simulation and optimization of RBF funded programs, that serves as a Decision Support System (DSS) for borrowers while implementing RBF. The Program-For-Results (P4R) mechanism, offered by the World Bank (WB), was used as one of the RBF mechanisms for verifying the developed framework. A model was developed for guiding borrowing governments through the full processes of P4R. The proposed model provides governments a step-by-step guide through each stage from initiation to program closing. For verification, the model was applied on a case study for presenting its capabilities. It was validated using the Sustainable Rural Sanitation Services Program (SRSSP) in Egypt, and it showed an improvement in the overall financial standing of the government. This model was developed and applied on the P4R mechanism; however, it applies to any other RBF mechanism as they share the same concepts and mechanisms.

Keywords: Optimization, finance-based scheduling, Managing Multiple Projects, Cash Flow, Infrastructure, genetic algorithms

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LIST OF ABBREVIATIONS

ACG	Anticorruption Guidelines
ADB	The Asian Development Bank
AFDB	The African Development Bank
APA	Annual Performance Assessment
BP	Bank Policy
CAS	Country Assistance Strategy
CEB	The Council of Europe Development Bank
CPM	Critical Path Method
CPS	Country Partnership Strategy
DLI	Disbursement Linked Indicators
DPF	Development Policy Finance
DSS	Decision Support System
E&S	Environmental and Social
EBRD	The European Bank for Reconstruction and Development
EF	Early Finish
EIB	The European Investment Bank
ES	Early Start
FF	Free Float
FG	Finance Gap
GA	Genetic Algorithms
IBRD	International Bank for Reconstruction and Development
ICR	Implementation Completion and Results Report
IFC	International Finance Corporation

IFI	International Financial Institutions
IIB	The International Investment Bank
IMF	International Monetary Fund
IPF	Investment Project Finance
IRA	Integrated Risk Assessment
IsDB	The Islamic Develoment Bank Group
IVA	Independent Verification Agent
JICA	Japan International Cooperation Agency
KFW	The Reconstruction Credit Institute (Kreditanstalt für Wiederaufbau)
LF	Late Finish
LIBOR	London Inter-Bank Offered Rate
LS	Late Start
MAS	Monthly Average Spending
MENA	Middle East and North Africa
MHUUC	Ministry of Housing, Utilities and Urban Communities
MIGA	The Multilateral Investment Guarantee Agency
MoF	Ministry of Finance
MPM	Multiple Project Management
NSGA	Non-dominated Sorting Genetic Algorithms
OEEC	Organization of European Economic Cooperation
OFID	The OPEC foundation for International Developemnt
OP	Operations Policy
P4R	Program for Results
PAD	Program Appraisal Document

PAP	Program Action Plan
PBCG	Performance Based Capital Grants
PCN	Program Concept Note
PDO	Program Development Objective
PERT	Programme Evaluation and Review Technique
PID	Program Information Document
PMU	Project Management Unit
R.A.	Result Area
RBF	Results based finance
SECPO	Policy and Operations Unit of the Secretariat
SORT	Systematic Operations Risk Rating Tool
SRSSP	Sustainable Rural Sanitation Services Program
TF	Total Float
USAID	The United stated Agency for International Development
VBA	Visual Basic Applications
WB	World Bank
WSC	Water Sanitation Company
WWT	Waste Water Treatment

CHAPTER 1: INTRODUCTION

The period between World War I and World War II witnessed a lack of cooperation between countries, especially during the depression period that took place in the 1930's. This caused higher rates of unemployment and economic turmoil. To avoid the repetition of such negative events, International Financial Institutions (IFI) were initiated. These are institutions which are commonly established by several countries aiming to regulate the cooperation between them. Following World War II, the Bretton Woods institutions, International Monetary Fund (IMF) and International Bank for Reconstruction and Development (IBRD) (currently a member of the World Bank group) were initiated in the United States of America. Similarly, the Organization of European Economic Co-operation (OEEC) was instituted in Europe (Bakker, 1996) (Bahrgava, 2006).

The main driving value of these institutions is that economic stability and prosperity in all countries eventually leads to world peace. All IFIs have some basic principles in common for their operations, such as: (1) they all aim at the freedom of capital movements and international trade; (2) try to support countries to maintain their economic and monetary stability internally and externally; (3) all member countries must take into consideration the interests of other countries in their policies; and (4) more efforts should be dedicated to under-developed countries offer them better economic conditions whenever possible (The World Bank, 2013).

To be able to make independent decisions, these financial institutions have to have their own sources of income. Most of these IFIs are actually profit making. Some of them were able to build-up significant capital and reserves that help them have buffer reserves in case of any shortages in funds and also improve their position through negotiations with member countries.

1 . 1 Funding Mechanisms for Infrastructure Projects

It is very important to efficiently select the appropriate funding mechanism as it represents a commitment on both the funding agency and the entity receiving funds. The most appropriate funding mechanism has to generate less government spending while getting higher funds. It is commonly agreed that public finance, from IFIs, is cheaper than commercial/private finance. Public funds are commonly limited in amounts, number of projects to be funded or time period over which they are funded. It is also preferred that any selected funding mechanism can be efficiently and easily understood and managed by local agencies. There are several financial instruments that can be used to support infrastructure projects through IFIs, namely; (1) Grants, (2) equity, (3) Debt / Loans, (4) Asset Backed securities, (5) Guarantees and Insurance and (6) Results Based Financing (Zahran & Ezeldin, 2016-A).

1 . 1 . 1 Grants

Grants are a form of financial support offered by IFIs to reduce financing burden on governments. Grants involve no fiscal return for the funding agency. These grants aim to decrease initial costs of infrastructure facilities by offering governments a non-refundable financial support. This eventually decreases the price of the end product for customers (e.g. a lower price of electricity in case of power plants). Moreover, grants do not encourage developers to create specific revenue from their projects for repayment. Grants are considered the simplest to implement among other financing techniques as they do not involve extensive due diligence on the financial outcomes of the projects, on the other hand, the project has to meet the desired objectives of the grant.

1 . 1 . 2 Equity

Equity funding is considered a long-term investment presented by the funding agency. In this case, the funding agency invests an amount of money in high-risk projects aiming to generate revenue from executing the project. Equity funding most commonly targets new technologies and projects/companies with a higher potential of growth. It is aimed that the return from the project/company is high due to the high risk associated with this type of funding. To avoid such a high risk, it is preferred that the supported project/company is in a well-developed financial market which facilitates the exiting process. Therefore, such funding mechanism may not be valid in most of the developing/low-income countries.

1 . 1 . 3 Debt/Loans

Debt/loans are a form of financial support where financial institutions provide governments with an amount of money for their projects. Government repays this amount through instalments over an agreed period after adding an agreed interest rate. Most commonly the interest rate added by IFIs is lower than commercial banks interest rates and the return period is longer. This eventually decreases the cost of financing infrastructure projects. In addition, it increases credibility of governments when applying for long-term financial support from commercial banks. Debts/loans are considered the most commonly used financing mechanism. The obligation on debtors to repay instalments incentivizes the success of projects to generate sufficient revenues.

1 . 1 . 4 Asset-backed securities

Asset-backed securities is a form of financial support which is given to governments while being backed by the future cash flows of already available projects. In this case, repayment is secured by expected cash flows, which is considered equivalent to bond offering. This type of financing is used in expanding or refinancing projects that are already generating positive cash flows. This reduces the risks of not returning the borrowed amounts which in-turn reduces the cost of finance. The use of asset-backed securities involves highly detailed due diligence to ensure that current and future projects are going to generate sufficient cash flow for securing funds and debt repayment.

1 . 1 . 5 Guarantees and insurances

Guarantees and insurances are not considered direct financing techniques; however, they offer protection for financiers in markets with high risks. This enables governments, having unstable market conditions, to get financing at acceptable costs. In both cases of guarantees or insurances, the guarantor or insurer agrees to cover or share any costs or losses associated with the target project in return for a fee or premium. In case of guarantees, the guarantor offers the guarantee for the financier against the performance of the borrower. This means that the guarantee would cover a portion of any losses occurring to the financier. Commonly, the portion of losses covered by the guarantor decreases, as losses increase in order to encourage the financier to take corrective actions against occurring risks. In case of insurance, the financier expects to receive the proceeds of insurance payout as a protection against the performance of the borrower. It insures against any losses occurring due to unexpected conditions that may affect the outputs of the project. Both guarantees and insurance require extensive due diligence for all involved parties and the design of the project which may require a large database of relevant risks and their associated effects.

1 . 1 . 6 Results Based Finance

Results Based Finance links the payment of funds to the delivery of pre-agreed outputs, so the borrower receives the agreed payment for finishing specific stages in a project/program. This transfers several risks associated with these projects from funders to borrowers, such as the risk of funds not achieving their desired outputs. It also incentivizes borrowers to deliver their projects according to the agreed schedules and outputs. The borrower starts by pre-financing the projects and payments are made only after it delivers the agreed outputs or services. This process commonly involves a third party for verifying that the agreed outputs were reached.

1 . 2 International Financial Institutions

An analysis of the roles and responsibilities of International Financial Institutions and their previous roles internationally was performed (Zahran & Ezeldin, 2016-A). It can be concluded that each IFI has its own objectives for supporting other countries in need for financial aid. IFIs generally support other lower-income countries through several financial instruments, according to their rules and regulations. Table 1 compares between IFIs based on the amounts of funding provided for the below areas (The World Bank, 2011) (KFW Development Bank, 2015) (International Finance Corporation, 2015) (European Investment Bank, 2015) (USAID, 2015) (AFDB, 2015) (ADB, 2015) (IIB, 2015) (IsDB, 2015) (JICA, 2015) (OFID, 2015) (MIGA, 2015):

(1) The most commonly applied financial mechanisms, according to the amounts lent in each mechanism

(2) The sectors receiving the highest amount of funds from such IFI and

(3) The region receiving the highest amount of funds from such IFI.

Table 1: Analysis of IFI

IFI	Main Financing Mechanism	Main operating sector	Main operating region
IBRD	Investment Project Finance	Public administration, law and Justice	Europe and Central Asia
KFW	Promotional Loans	Economic infrastructure and services	Sub-Saharan Africa
IFC	Loans	Financial markets	Latin America and the Caribbean
CEB	Loans	Supporting MSME.s	Europe
EIB	Loans	Transport	Europe
USAID	-	Economic Growth	Asia
AFDB	Loans	Infrastructure	Africa
ADB	LIBOR-based loans	Transport	Asian and pacific
IIB	Loans	MSME.s	Europe
IsDB	Murabaha	Energy	Islamic countries
JICA	Loans	Electric power and gas	Asia
OFID	Public sector lending	Energy	Africa
MIGA	Guarantees	Infrastructure	Europe and Central Asia
EBRD	Loans	Financial Institutions	Eastern Europe and the Caucasus

1 . 3 Results-Based Finance

This research is focused on the results-based financing mechanism offered by international financial institutions. One of the main concepts of results-based finance is that disbursements are linked to the achievement of pre-agreed results. In this case, the borrower receives the agreed payments for finishing specific stages in a program/project. This transfers several risks associated with funding these projects from the funders/financiers to borrowers. It also incentivizes borrowers to reach agreed milestones in time to maintain their cash flows, as the borrower starts by pre-financing activities/projects and then payments from the funding agency are received after results are achieved. This process commonly involves a third party, called the Independent Verification Agent (IVA), for verifying that the agreed results were reached (Zahran & Ezeldin, 2016-B). This research focuses on the Program-For-Results funding mechanism offered by the World Bank, as an example of the results-based financing mechanisms offered by IFIs. This is because P4R is well structured with detailed standards and regulations for each stage within its application, from initiation to closing. General guidelines within these regulations still apply to other RBF mechanisms, while differences lie within the flow of documentation and reporting procedures.

Figure 1 presents the application process for the P4R mechanism showing the transfer of information and funds between the bank and the borrowing government. It starts by an agreement between both the WB and the borrowing government about the program scope and main framework for the disbursement of funds, called Disbursement Linked Indicators (DLI). After an agreement is reached the bank starts in program implementation. Once the government achieves a DLI, it is reported to the WB and approved by a third party then the bank disburses the allocated amounts. This cycle continues until the program duration finishes and program ends. The following section describes in detail each stage of the P4R application and the roles and responsibilities of each party.

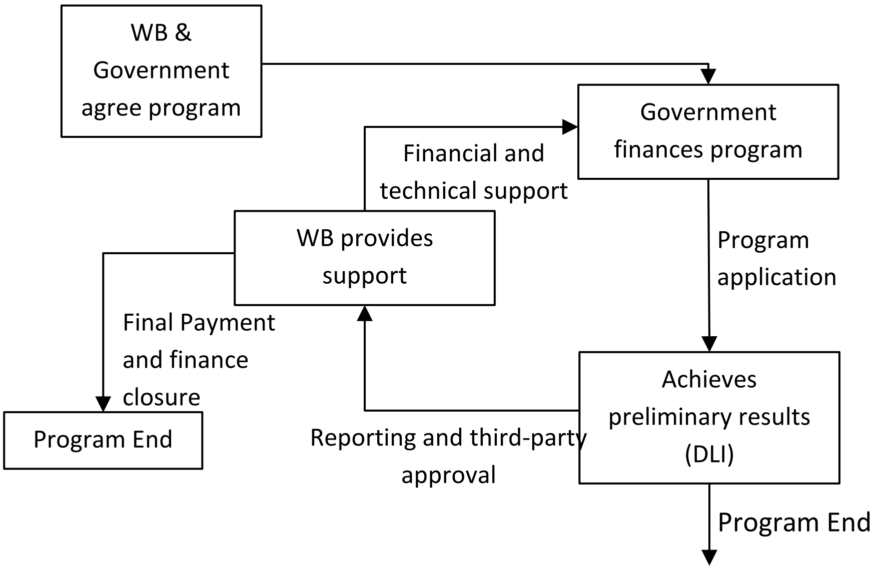

Figure 1: P4R Application process (Ezeldin & Zahran, 2017-A)

P4R is shaped through four main features (1) it supports the programs of borrowers, either newly developed programs or already existing ones, the WB shows flexibility within the P4R mechanism to support any kind of programs in any sector and within any country/region, (2) it provides disbursements upon the achievement of results (called disbursement linked indicators (DLIs)), these DLIs are agreed during the preparation stage by both the borrowing government and the WB team to eliminate any chances of conflicts following project initiation, (3) it focuses on strengthening the institutions within the borrowing country that may contribute to the success of the funded program. This is to ensure the sustainability of the effects of such programs and (4) it assures that the finance offered by the WB is directed to programs that serve the environment and other social aspects. These are guaranteed through proper environmental and social assessments performed through the preparation stage and monitoring of the program implementation to ensure compliance with bank policies.

1 . 3 . 1 History of Program-For-Results

P4R funding mechanism was initiated in 2012 by the World Bank to address demand from clients all-over the world for results-based financing mechanisms (The

World Bank, 2016-A). P4R was introduced to support bank clients in achieving their own programs and providing technical support through their experience in similar projects (Saadah, 2015). P4R addresses the gap between the Development policy financing (DPF) and Investment project financing (IPF) mechanisms previously offered by the WB. It offers both technical assistance to institutions of the borrowing countries, such as the case in DPF, and financial support for programs linked to the achievement of their results, such as the case in IPF. P4R enables the WB to work in countries with weak systems as it targets improving these systems and aims at strengthening institutions and capacity throughout the lifetime of the programs.

Since P4R was initiated, it has been implemented in several developing countries in different regions. Table 2 shows the number of approved operations and operations being prepared (in-pipeline) as of February 2016. It can be observed that P4R is mainly applied in Africa and the MENA region (The World Bank, 2016-B). Table 3 indicates the sectors that P4R has been applied in until February 2016. It shows that a high percentage of the current P4R operations is directed to the Water sector, for water supply and sanitation projects.

Table 2: P4R operations by Region (The World Bank, 2016-B)

Region	Approved operations	Operations in pipeline
Africa	14	3
East Asia and Pacific	3	4
Europe and Central Asia	2	3
Latin America and Caribbean	3	1
Middle East and North Africa	7	8
South Asia	6	3
Total	35	22

Table 3: P4R operations by Sector (The World Bank, 2016-B)

Sector	Approved operations	Approved Funding (USD Bn)	Operations in Pipeline	In Pipeline funding (USD Bn)
Agriculture	1	0.1		
Education	2	0.4	3	0.6
Energy and Extractives			6	1.8
Environment and Natural Resources			1	0.5
Finance and Markets	1	0.5	2	0.4
Governance	5	0.3	1	0.1
Health, Nutrition and population	6	1	2	0.6
Poverty	1	0.1		
Social Protection and Labor	2	0.9		
Social, Urban, Rural and resilience	7	1.6	5	1.2
Trade and Competitiveness	1	0.4	1	0.1
Transport and ICT	3	0.3	1	0.4
Water	6	2.7		
Total	35		22	

1 . 4 Program-For-Results Two-Year-Review Report

In year 2012, following the approval of the P4R lending instrument, the World Bank's Board of Executive directors requested the performance of a follow-up review of the instrument in two years (The World Bank, 2015-B). In March 2015, a report titled "Program-For-Results: Two-Year Review" was issued by the operations policy and country services department in the World Bank to address the request initially made by the WB Board of Executive directors back in 2012. This review had two main objectives (1) to perform an assessment of the experience of bank staff, borrowing countries and third-parties in applying the new funding mechanism over these two years throughout the life cycle of P4R (from the identification phase to the closing phase) and (2) the identification of lessons learned and any suggested changes to the originally proposed framework to help improve its implementation. This review involved several reviews of literature, desk reviews, structured interviews and surveys of all stakeholders who were involved in any of the stages of P4R operations.

One of the main observations concluded from the analysis of surveys was that most of the interviewees faced the problem of the lack of experience of stakeholders involved in the application of P4R. This leads to the need for further guidance and training into the application of P4R. Several feedbacks also stated that, as this is the first time for P4R to be applied, following the use of Investment Project Financing (IPF) and Development Policy Financing (DPF) for a long period, most of the stakeholders were influenced with the IPF and DPF tools and techniques while applying P4R. Some experts claimed that the performance of assessments through the preparation stage, by the World Bank task team, showed the need for further training for performing these assessments due to their importance in directing the Bank's decision for funding government's programs. Most of the experts reported the need for a clear understanding and knowledge of all previous experiences in relevant sectors for guiding any programs in-pipeline.

The main challenges defined were (1) the proper definition and settlement of DLIs, (2) the application of the WB Anti-Corruption Guidelines (ACG), (3) the impact of the exclusion of some activities from programs due to the P4R rules/guidelines of excluding some types of activities from supported programs and (4) the performance of assessments on programs and their effect on the program's outputs and integrity.

1 . 5 Problem Definition

One of the main challenges facing governments in managing programs financed through results-based mechanisms, specially infrastructure programs, is the need for managing multiple projects simultaneously while aiming to minimize spending on the program and minimizing the borrowing interest amount as much as possible. In this case, the government needs to balance its cash flow through proper management of transfers to its implementing agencies and transfers from the funding agency. This develops a complex problem driven by the need for obtaining money from the lending entity as early as possible for financing its cash flow, while also demanding to postpone any unrequired funding as much as possible to avoid any unnecessary payment of interest. Infrastructure projects, financed by governments, are known to have a low return on investment, that may not enable the government to use its return for financing other projects.

The failure to control the budget of projects and their required financing is considered one of the main reasons for the failure of businesses in the construction sector (Arditi, et al., 2000). This similarly applies for governments, where any projects that may have an impact on the government's general budget, can be cancelled or delayed until required funding is available. This requires extensive analysis of the cash flow of projects managed/financed by the government.

The simulation and optimization process of this type of programs is complex and requires extensive analysis of the available alternatives for reaching an optimum situation for the government with respect to its spending on the program and improving its benefit from the borrowed loan. The financial management of this size of programs, involves the management of several layers of transactions that have to be managed by the government. The timing and magnitude of these transactions highly affects the overall standing of the program cash flow. This problem may be similar to a common client-contractor relationship; however, the involvement of different parties within the financing cycle requires a different analysis of the overall program's finance.

As shown in Table 1, loans is the most commonly used financing mechanism between IFIs, this reflects on the knowledge of borrowing countries of other mechanisms and their ability to manage them. This was also evident in the feedback received from P4R stakeholders in the two-year review report mentioned earlier. This specifically reflects on the ability of these countries to operate using results-based financing mechanisms. It also hinders the ability of governments on expecting different solutions/alternatives that may optimize the design of their programs. Governments may require some guidance through the application of such mechanisms, while benefiting from previous experiences.

The model of results-based finance is increasingly being researched and applied by international financial institutions (IFI). The application of Program-For-Results mechanism has been growing exponentially since initiated, from 35 operations supported by nearly $ 8.1 billion by year 2015 (Gelb, et al., 2016), up to 96 operations supported by nearly $ 26 billion by year 2018 (The World Bank, 2018). This drives the need for properly managing these amounts of funds.

1 . 6 Thesis Aim and Objectives

The aim of this research is to: *develop a framework that guides governments of developing countries through the application of Results-Based funding mechanisms offered by international financial institutions*.

This aim is achieved through the following research objectives:

1. Developing a decision support model that:
    a. Provides borrowers guidelines when performing results-based finance assessments

b. Supports borrowers throughout the planning and negotiation phases of RBF

c. Applies finance-based scheduling/optimization

d. Incorporates actual implementation progress and continuous optimization

2. Verify and validate the model

1 . 7 Research Methodology

To achieve the above-mentioned research objectives, this research is divided into five main stages, as shown in Figure 2. This Research was initiated by a review of literature related to International Financial Institutions and their available funding mechanisms (Zahran & Ezeldin, 2016-A). This review then focused on available results-based funding mechanisms offered by development lending institutions. Program-For-Results mechanism was then selected as a sample of these mechanisms. A review of literature published by the World Bank and other development partners was performed on the Program-For-Results mechanism and its required tools and techniques (Zahran & Ezeldin, 2016-A) (Zahran & Ezeldin, 2017-A). Further review of literature was done in the fields of finance-based scheduling and the management of multiple projects in order to explore possible techniques required for the management of this type of programs. This led to the definition of the main problem behind this research. For solving such problem, a framework was proposed for supporting governments in applying the P4R mechanism (Zahran & Ezeldin, 2017-A). Two main models were developed, (1) the risk assessment model and (2) cost and scheduling simulation and optimization model (finance-based scheduling). These two models are then integrated into a user-friendly decision support system that guides the government throughout the RBF processes, from initiation to program closing. The proposed approach and model are then verified using a case study, for implementing all available tools within the model, then validated using the Sustainable Rural Sanitation Services Program in Egypt.

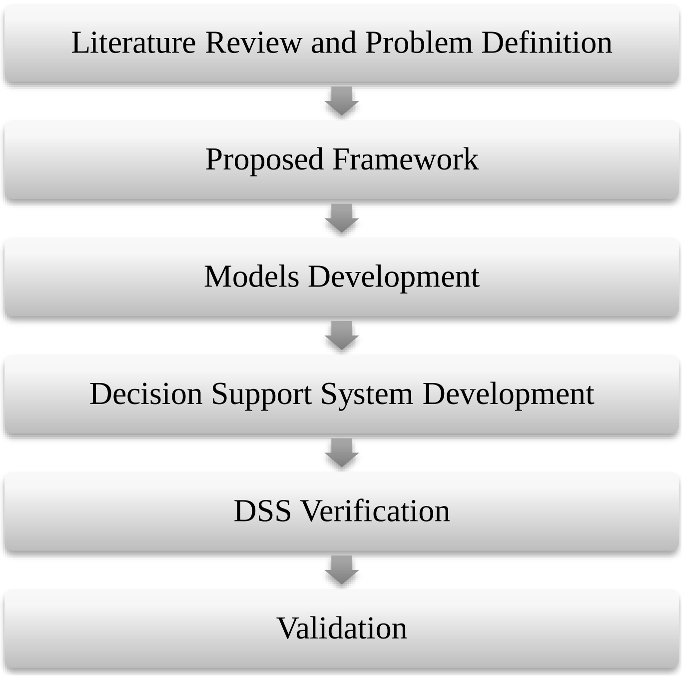

Figure 2: Research Methodology Flow Chart

1 . 8 Thesis Organization

In order to achieve these objectives, the thesis is organized as follows, Chapter 1 is an introduction to the main funding mechanisms offered by IFIs for supporting infrastructure projects. It presents a list of the main International Financial Institutions worldwide, their roles and their financing mechanisms. Introduces what is RBF, the problem statement, thesis aim and objectives, and the research methodology.

Chapter 2 provides a review of related literature in fields of managing multiple projects, the application of optimization techniques in construction, concepts of finance-based scheduling as discussed in previous research. The discussed research in this thesis is considered complementary for the developed decision support system, as the management of programs funded by Program-For-Results mechanism requires the knowledge of multiple projects management techniques and finance-based scheduling.

Chapter 3 provides a review of results-based finance methods offered by IFIs. It then focuses on Program-For-results related literature, describes one of the main pillars of P4R which is DLIs, covers the details of P4R application and provides a description of fees added by the WB on programs supported by P4R.

Chapter 4 is divided into two main sections. The first section describes the applied research methodology, and the full process of research stages starting from the literature review to the validation of the developed model. It presents the main framework of the decision support system and briefly describes processes used for applying such framework and validating it. The second section presents the developed model following the research framework and demonstrates its details of operation. It guides the user step-by-step throughout the model. It also serves as a manual for the application of the DSS.

Chapter 5 describes the verification process of the developed model and its application on a case study, that replicates a typical program, but with fewer activities. This case study is used to present all model capabilities and verify it is able to provide realistic results.

Chapter 6 describes the validation process of the developed model and its application on the Sustainable Rural Sanitation Services Program (SRSSP) in Egypt. It presents the original and optimized results of the model and the effect of applying the model on the program.

Finally, Chapter 7 provides the conclusion of this research and presents its main contribution/support to developing countries considering the application of RBF mechanism. It also features the main areas for future research in this topic.

CHAPTER 2: LITERATURE REVIEW

A crucial factor for governments in managing infrastructure programs funded by IFIs, is the ability to coordinate financing amounts received with required expenditures, specially under results-based funding mechanisms. This aims to execute the desired program with the least possible burden on the country's general budget. Several researches focused on scheduling single projects according to the available funding cash flow. In case of single projects, contractors commonly seek financial support from banks for financing their cash flow gaps. Previous research introduced supporting tools and techniques guiding contractors on efficient management of bank tools for maintaining a healthy cash flow profile for their projects, that does not affect the progress of project activities (Elazouni & Gaballah, 2004). Bank overdrafts is considered the main financing method for construction projects (Ahuja, 1976). The use of bank overdrafts is done through an agreement with a bank for providing support for contractors for having negative balances in their accounts for a limited time with an agreed credit limit. This enables contractors to have sustainable cash flow levels that may not affect any project expenditure requirements throughout the project. This negative balance is covered by the end of the project, or before, according to the cash flow profile and profit margins of project, through the receipt of project invoices.

Program management (Patanakul & Milosevic, 2008-a), describes the management of a group of projects, of different natures, sharing the same goals and leading to a particular output; however, Multiple Project Management (MPM) describes the management of several project that might not have common goals, although managed by the same entity or project manager. This kind of Project management is currently taking hold in many businesses, due to its savings with regards to the human resources. Current literature focuses on single projects management more than multiple projects or programs management.

This chapter is divided into four different sections. The first section describes the application of optimization techniques in the construction industry. It describes in detail methods that are used for applying optimization in solving problems within the industry. The second section describes the problem within the application of project management tools and techniques in a multiple-projects environment. The third section describes the concept of finance-based scheduling and how it was approached in previous research. The last section describes the application of optimization techniques in a multiple-projects environment for reaching required goals/objectives. Finally, a summary is provided for this chapter.

2 . 1 Optimization in Construction

Scheduling Optimization techniques have been utilized in the planning process of construction projects. Applications include (1) time-cost tradeoff, where the optimization goal focuses on balancing the total duration of the project with its direct cost (Hegazy 1999-a), (2) Resource leveling, where the optimization objective aims to minimize the variability of resource requirements throughout the project duration (Moselhi & Lorterapong 1993), (3) Resource allocation, which aims to utilize a limited amount of resources while reducing its effect on the project total duration (Hegazy 1999-b) and (4) finance-based scheduling, that targets the minimization of the cost of capital when financing construction projects (El-Abbasy 2015).

There are several methods and algorithms that were developed for applying optimization techniques on construction schedules (Zhou, et al., 2013). These methods are classified into three different types, (1) mathematical methods, (2) heuristic methods and (3) metaheuristic methods.

2 . 1 . 1 Mathematical Methods

Mathematical methods include the (a) critical path method, (b) Linear programming, Integer programming and Integer Programming/Linear Programming Algorithms and (c) dynamic programming.

The Critical Path method (CPM) is widely used in planning, especially in the construction industry, since developed in the 1950s (Kelley & Walker, 1959) (Kelley, 1961). The main drawback of the CPM is that it can only deal with one objective. The Programme Evaluation and Review Technique (PERT) is commonly used with CPM in scheduling construction projects. CPM generally depends on the logic of relationships between activities and their durations. This provides a final time schedule for the project that includes durations of activities, their relationships and their early and late dates (Samuel, 2010). It is concerned with the fact that critical activities are activities forming the critical path of the project, which is the longest path in the project, while other activities are considered float activities which have the ability to be delayed without affecting the total duration of the project. One of the main limitations of the CPM technique is that it depends on time and precedence constraints. This limitation was overcame through a two-stage approach, where the first stage defines the scheduling requirements while the second stage analyzes and allocates resources according to defined constraints (Antill & Woodhead, 1982) (Moder, et al., 1983) (D, 1985) (Tamimi & Diekmann, 1988).

Linear programming is an analytical algorithm that is used to solve optimization problems having linear objective functions with linear constraints (Kantorovich, 1940).

In this case, optimization problems are expressed through mathematical equations and are solved through criss-cross algorithms, simplex algorithm or interior point method (Liu, et al., 1995). Same concepts apply to integer programming where the answer is required to be an integer, following the same constraints. Integer programming is solved through several approaches such as the branch and price method, branch and bound method, cutting-plane method and branch and cut method (Chen, et al., 2010). Integer and Linear programming techniques were applied in different variations in the construction industry. They were applied for solving discrete and linear relationships between activities in an optimization problem for scheduling activities of a construction project of a repetitive nature in the highway sector (Meyer & Shaffer, 1963). They were also used for applying resource leveling in highway construction projects (Meyer & Shaffer, 1998). Integer and Linear programming were then used for applying financial scheduling optimization on construction projects time schedules (Elazouni & Gaballah, 2004).

Dynamic programming is a different type of mathematical methods which is applied on more complex problems that can be split into several simpler problems (Dasgupta, et al., 2006). This approach was applied in solving time-cost tradeoff problems (Robinson, 1975) (Moselhi & El-Rayes, 1993).

2 . 1 . 2 Heuristic Methods

These are methods that depend more on previous experiences in solving problems. An approach was developed as an alternative for the CPM, for scheduling precedence in scheduling problems. It mimics flow charts and flow diagrams for devising a “circle and connecting line” diagram that is used to solve time-cost trade-off problems (Fondahl, 1961). This approach is currently implemented by project management software. Another algorithm was developed that has the ability to reduce the total duration of a project to a desired duration, at the least possible cost (Siemens, 1971). This algorithm is applied on projects without the use of computers; however, it does not guarantee providing an optimal solution for the time-cost trade-off prblems.

A method for CPM scheduling was proposed for optimizing project total duration for minimizing the project total cost (Moselhi, 1993). This method resembles the structural analysis method called “direct stiffness method”, where the project time schedule is represented by a structure that has a compression value that is equivalent to the project compression, and the total cost of compressing this schedule is the sum of forces on all members of the structure.

A heuristic method was developed by Zhang et al (2006) for applying time-cost trade-off on projects of a repetitive nature. This method considers resource constraints while minimizing the project overall duration. It depends on categorizing activities in different groups to be scheduled simultaneously for minimizing the project overall duration. The combinations are later evaluated according to their effect on the overall duration and cost of the project. This method was integrated in a project scheduling framework. The main drawback of this method is that it did not consider the overall effect of minimizing project total duration on the relation between the direct and indirect costs of the project.

Other heuristic methods were applied on variations of construction scheduling optimization, such as the consideration of cash constraints on scheduling multiple projects (Elazouni, 2009) and introducing the concept of multi-skilled labor for overcoming the resource shortage problem (Hegazy, et al., 2000). In general, Heuristic methods require a lower amount of computations than the mathematical methods, and some of them can be calculated manually without the use of computers.

2 . 1 . 3 Metaheuristic methods

Heuristic methods have several drawbacks such as having the ability to only consider one objective which leads to the consideration of a local optimum only and does not guarantee reaching global optimum solutions. They also do not search into all possible solutions for an optimum output, they only provide a single output that may not be of interest for construction planners. Metaheuristic methods were developed to overcome these drawbacks. These are used for solving problems of a huge number of possibilities that cannot be solved manually. These methods use iterative calculations according to the set criteria and constraints for finding an optimum solution. The developed metaheuristic methods were inspired by natural processes where, (1) genetic algorithms mimics the natural idea of the survival of the fittest genes in human survival process, (2) ant colony optimization which mimics the organization of ants in their colony and their ability to find the best path between food sources and their nests and (3) particle swarm optimization, which assumes that available solutions are particles that are spread in the solutions space for finding the best solution according to its location.

Genetic algorithms method is considered the most widely used approach in applying optimization on construction scheduling problems (Zhou, et al., 2013). It is an algorithm that searches through all possible solutions randomly and reaches a near optimum solution through evaluating the resulting outputs based on the desired objective function. This relates to the survival of the fittest concept through keeping the best reached results so far on the top of the chain, until a better result is achieved, to replace it. An optimization problem is broken down into chromosomes that represent the set of variables forming the problem, within each chromosome there is a number of genes which represent each variable. These variables are guided by a set of constraints of the problems, for example they have to be within a specific range or have to be integers. Once an initial population is formed, its fitness is evaluated according to the objective function, then the algorithm starts in randomly changing variables and evaluating each of the resulting combinations (chromosomes). This method does not rely on extensive calculations, so it could be used in complicated construction optimization problems as it can be easily used in finding near optimum solutions.

Genetic algorithms method was extensively used in applying optimization on construction projects. It was used in applying resource leveling and resource allocation concepts on construction schedules (Chan, et al., 1996), it was also used in applying multi-objective optimization for solving the time-cost trade-off problem (Feng, et al., 1997) and was used for integrating the time-cost trade-off, resource leveling and resource limitation problems in a multi-criteria model (Leu & Yang, 1999). Hegazy (1999-a) developed an approach for improving the practicality of using GA through integrating it with the commercially used scheduling software called Microsoft Project. This model developed for improving the abilities of this software in dealing with time-cost trade-off problems. These approaches/models were later modified and improved for overcoming any drawbacks in the GA mechanism (Li, et al., 1999) (Hegazy, 1999-b) (Senouci & Eldin, 2004) (Sriprasert & Dawood, 2002) (Zheng, et al., 2004) (El-Rayes & Kandil, 2005) (Kim & Ellis Jr, 2008)

Ant Colony optimization method is considered a natural learning technique that resembles the learning technique of ants in finding the optimum path for desired trips

(Zhou, et al., 2013). Ants learn from each other by taking the path that most of the previous ants took and gradually adds to this path better shortcuts. So, the whole colony learns from the behavior of guided results. Taking this to construction scheduling, the optimization problem is represented on a weighted network, then first group of probabilities start to define the whole horizon of solutions. The evaluation criteria defines which path is the best to take for the later trials, until the stopping criteria is achieved. The Ant Colony Optimization method consists of four components: (1) simulating the problem, which represents all possible trips of the ant from the start point to the end point, (2) the probabilities/weights for selecting among the paths available in the trips, (3) a criteria for updating the learned lesson from the path taken from the start to the end through each path and (4) the stopping criteria that is used from stopping the repetition of trials. This method was also applied in several researches for addressing the time-cost trade-off problems (Ng & Zhang, 1997) (Afshar, et al., 2009) (Lakshminarayanan, et al., 2010).

Particle swarm optimization solves optimization problems through iterations, but through a different criterion. It considers available variables as particles moving in the space of available solutions and each iteration is evaluated according to the desired objective function (Eberhart & Shi, 1998). The particle swarm method was first applied by Zhang et Al (2006-b) in construction optimization problems for minimizing project total duration while considering resource constraints. It was later modified for solving optimization problems in underground mining projects, by adding a crossover criteria for improving the position of the particles efficiently and obtaining better solutions (Guo, et al., 2010). It was found that the particle swarm method does not necessarily provide local or global optimum solutions, due to the methodology used by this method, which only ensures better results and not global optimization.

2 . 2 Managing Multiple Projects/Programs

The management of mega infrastructure programs requires the implementation of Managing-Multiple-Projects/Programme-Management concepts. A programme is defined as “a group of projects that are managed in a coordinated way to gain benefits that would not be possible were the projects to be managed independently” (Ferns, 1991). Programme Management is defined by Turner and Speiser (1992), as “the process of coordinating the management, support and setting of priorities on individual projects, to deliver additional benefits and to meet changing business needs”.

The difference between managing single projects and managing programs is not only in the number of tasks performed. In case of program management, priorities and time management can be the leading driver of performed activities (Patanakul & Milosevic, 2008-b). Program managers are responsible for the management of sub-projects each according to its goals, while managing to maintain a smooth flow of management activities all over target projects. Management of different types of projects, even if they were simple and straightforward, creates a complexity in management due to the difference in required tools and techniques for managing each project separately. It commonly involves strategic and financial planning for the required outputs of each task within different projects (Platje, et al., 1994). This has to target the overall success of program rather than the success of each individual project (Shenhar & Thamhain, 1994).

There are several challenges that distinguish program/portfolio management from single project management, these include: (1) the combination of different types of projects, (2) the balance of available resources among projects, which are commonly limited, (3) the management of full program/portfolio for achieving an optimum output and (4) managing transferals between projects throughout the program lifecycle (Elonen & Artto, 2003) (Engwall & Jerbrant, 2003) (Dooley, 2000) (Cooper, et al., 2000) (Dooley, et al., 2005). The failure of portfolio management has been related to (1) failure in leadership, (2) inadequate strategic planning, (3) insufficient monitoring and control of projects and processes on the overall aim of the program and (4) discoordination between actions/activities performed and program objectives (Dooley & O'Sullivan, 2003).

In case of multiple projects management in the infrastructure sector, due to the difference in nature and technical requirements of each project, it creates higher complexity on the program manager in coordinating between projects of different natures, locations or even technologies. Infrastructure projects commonly include higher numbers of activities running in parallel in each project, this translates into multiples of activities managed by program managers in case of managing several infrastructure projects simultaneously. In other types of projects, program managers may integrate more of human management skills than technical knowledge (Katz, 1976); however, in case of multiple infrastructure projects, program managers may need to integrate both technical and management skills for effectively managing this type of projects, due to the amount of know-how incorporated.

2 . 3 Finance-Based Scheduling

Contractors commonly seek financial support from banks through credit lines (Ahuja, 1976). Credit lines enable contractors to have required cash for financing construction activities without having sufficient amounts in debit, so banks would charge contractors for any amounts in credit until they are covered in debit. In this case, contractors would deposit progress invoices in their credit-line account for reducing the amounts due. Credit lines commonly have limits that represent the maximum amounts a borrower can disburse at any point of time, this means that contractors have to plan their project schedules while considering this limit. Several researches studied the optimization of projects time schedule while considering finance charges, this concept is called Finance-Based Scheduling. These optimization problems commonly include the objectives of increasing profit and decreasing cost of capital/finance (Elazouni & Gaballah, 2004) (Elazouni & Metwally, 2005) (Abido & Elazouni, 2010) (Al-Shihabi & AlDurgam, 2017). Research then introduced multi-objective optimization that integrates financing and other constraints for optimizing projects time schedules (Elazouni & Metwally, 2007) (Fathi & Afshar, 2010) (Ammar, 2011) (Elazouni & Abido, 2014). These concepts were also applied in a multi-project environment (El-Abbasy, 2015) (El-Abbasy, et al., 2016) (El-Abbasy, et al., 2017).

Elazouni & Gaballah (2004) Introduced an integer-programming finance-based scheduling technique for producing schedules that balance cash-flow available with finance required for activities throughout the project. This model uses bank overdrafts as the main financing method for construction projects, it mainly took the contractor perspective in analyzing the project financing. This model aimed to balance the use of bank overdrafts for maintaining a financially stable relationship with banks offering such mechanism. The stability of employing bank overdrafts provides an indirect benefit of improving the position of contractors while negotiating overdraft terms with banks, as it provides better planning for both the bank and the contractor. It also enables contractors to have a control over their required cash, and not passing credit limits, which may lead to the delay of planned activities. This model employs integer programming optimization techniques on CPM scheduling, for achieving optimum time schedules from a financial view-point. It focused on the increase of projects duration to adapt for available credit limits. The method adopted by this research included four phases. It started by (1) “Devising initial scheme”, which involves the development of the project CPM schedule in bar chart format, according to the original inputs of the program, without considering any required changes. (2) “Devising an extension scheme”, this section starts in considering the effect of extending the project on the available cash-flow and financing requirements. It studies the effect of extending the project by specified durations that allow for stabilizing financing requirements. (3) “Model formulation”, this stage is responsible for the development of the integer programming model required for reaching the objective of minimizing the extension of the project total duration, while considering project constraints. These constraints are the amount of float available for each activity, the consideration of sequence of work and required relationships between activities and the specified credit limit available for the project. (4) “Searching for solution”, where the model starts in proposing new total durations for the project and adjusting project plan consequently to analyze its effect on project financing and reach the required objective. A prototype model was developed using Microsoft Excel as a spreadsheet modeling tool and VBA as a programming tool.

In year 2005, Elazouni and Metwally (2005), introduced a finance-based scheduling tool that aims to maximize the project profit using genetic algorithms optimization. It also considered minimizing the total duration of the project. This research focused on decreasing financing costs and indirect costs for maximizing profits. The main difference between this research and the previous one is that it included other parameters in the optimization process than extending project duration for achieving higher profits from the project. This technique was expanded later to allow for considering resource levelling, resource allocation and time-cost-tradeoff (Elazouni & Metwally, 2007). It introduced a technique that enables schedulers take resource constraints into consideration while performing finance-based scheduling. This technique also employs genetic algorithms for performing the optimization process. The goal of maximizing profit was also considered, through minimizing financing costs, overheads, direct costs and resource fluctuations.

An optimization model that applies "non-dominated sorting genetic algorithms" for optimizing the finance-based scheduling process of construction projects in case of the application of the line of credit financing method was developed by Fathi and Afshar (2010). This aims to provide an optimum combination between the project financing requirements and the available credit limits. The main objective of this model is to provide a non-dominated solution that balances the three solutions of adapting to the required credit limit, minimizing the total project duration and minimizing the total financing cost. This model provided an improved methodology for the application of the non-dominated sorting genetic algorithms, through improving its steps of implementation. These include (1) the generation of the structure of chromosomes, (2) the generation of the initial population based on the provided chromosomes, (3) the performance of offspring operators, (4) the evaluation of populations and their chromosomes based on the set objective functions, (5) the application of non-dominated sorting and (6) finally the update of populations and sorting newly developed solutions.

An optimization model was introduced by Ammar (2011) for the allowance for the time value of money for costs of activities within projects subject to the time-cost trade-off optimization problem. In general, time-cost trade-off problems assume that the costs of activities are constant throughout the lifecycle of the project, this model depends on the fact that the value of money changes with time, so it should be considered when planning for rescheduling any activities. This model used non-linear mathematical optimization technique for solving the time-cost trade-off problem while considering the effect of time value of money. This model had the objective of minimizing the project direct costs while considering discounted cash flows. The developed model provided three main features, (1) the consideration of time value of money, (2) the reflection of the time-cost relationship on the cost estimation of projects for providing realistic activity costs and (3) providing a guaranteed optimum solution. These features, when applied on projects, provide different results than comparable models in literature.

A multi-objective optimization algorithm was introduced to investigate the probability of balancing project resources, profitability and finance (Elazouni & Abido, 2014). This approach employs a fuzzy approach to evaluate solutions generated through a strength pareto algorithm, that defines optimal solutions between results obtained from a genetic algorithms model.

An alternative max-min ant system was introduced for performing finance-based scheduling (Al-Shihabi & AlDurgam, 2017). This research introduced three different max-min ant systems that generate solutions through different heuristic information, these are the durations, cost and the number of successor activities. This algorithm introduces a different approach for applying the ant system on solving this optimization problem, where it guides available solutions by imposing a minimum and maximum limit for the generated alternatives. This was found to avoid the generation of similar results and stimulate the diversification of evaluated alternatives.

Contractors commonly manage construction projects simultaneously, which imposes the application of multiple projects management financially. This means that any application of finance-based scheduling should be considered on the pool of projects managed by the company and not on individual projects separately. This ensures that negative cash flows from projects do not accumulate and cause cash-flow deficits that may lead to the delay/stoppage of projects (El-Abbasy, 2015).

2 . 4 Multiple Projects Optimization

The difference in nature between single project management and multiple projects management lies in the complexity of the coordination process for allocating resources and financing between projects for efficiently reaching the required goals. Several studies were performed to optimize project schedules with respect to project financing; however, these studies were concerned with short term contractor perspective for running projects. Concerns of these studies were between the decrease of spending on running projects, decreasing durations of projects, maximizing the achieved profit and decreasing the required financing costs (El-Abbasy, 2015).

El-Abbasy (2015) introduced a model for optimizing construction projects schedules while taking into consideration their financing and resource allocation. This model aims at supporting contractors in scheduling near-optimum multiple projects with respect to their available resources and finance. This is achieved by performing a trade-off between project objectives involving project cost, cost of finance, required credit, fluctuation in resources and generated profit. Finance-Based scheduling optimization was also applied by other researchers on a multiple projects environment (Abido & Elazouni, 2011) (Elazouni, 2009) (Liu & Wang, 2010) (Tabayang & Benjaoran, 2015) (Gajpal & Elazouni, 2015) (El-Abbasy, et al., 2016). Finance-based optimization research is commonly concerned with the contractor's perspective. Developed systems simulate the contractor-subcontractors and contractor-client relationships; however, none of the developed models analyze the client financing and scheduling strategy. The main difference between both approaches is the timing of financing required, contractors commonly utilize credit lines in financing their cash flows due to the fact that their payback periods are short term, relevant to the nature of construction projects. In case of clients, payback periods extend beyond project durations, so long-term financing is required. In case of mega infrastructure projects, managed by governments, managing multiple projects is shifted to a strategic level, where governments need to plan different types of activities. Also financing mechanisms offered by commercial banks for contractors, may not be available for governments. Government funded programs generally are not profit oriented; however, they are benefit oriented, where they seek to achieve the desired outputs with the least possible financing. This involves finance-based planning that decreases financial expenses, in case of loans, and keeping loan interest to a minimum.

A heuristic method was introduced by Elazouni (2009) for applying finance-based scheduling on multiple projects. This performs several steps that finally lead to the optimization of multiple projects schedules, these include the definition of cash flow availability, identification of scheduling alternatives for activities, the calculation of relevant cash flow for each of the developed alternatives, ranking of developed schedules according to the desired objective, providing an optimized time schedule for each project and provides an optimum time schedule. This method considers cash in-flows and outflows periods for simulating the overall cash flow management for contractors in the multiple projects environment. This period is then planned to only have activities that can be financed using available cash. This is achieved by the heuristic algorithm developed, where it works on scheduling only activities that fit into the credit limit available. This achieves an optimum utilization of available funds throughout the project.

A profit optimization model was proposed by Liu & Wang (2010) for contractors operating projects in a multi-projects environment. It used constraint programming for considering financial and cash flow requirements for maximizing overall profit from multiple projects. Constraints considered by this model are due dates settled for each project and credit limits. Liu & Wang later introduced an optimization model that applies Constraint Programming (CP) for problems of project selection and scheduling having resource constraints (Liu & Wang, 2011). This model has the objective of increasing the overall profit of all managed projects. It also considers time dependent resource constraints, these are resources that having different availabilities over time. It also considers available budget as a critical resource that is considered limited and should always be observed. This research then analyzed two different scenarios of (1) setting limits for the available budget that are time related, this means that the available budget can change by time, so spending on projects by the contractor can have two different values in different years. Another scenario (2) was to set different limits for resources over time and optimize the overall profit of projects. In both case the model optimized the overall profit of multiple projects analyzed. This enables contractors satisfy their needs concerning budget cuts and limitations on resources procurement.

A Strength Pareto Evolutionary Algorithm was introduced for optimizing the finance-based scheduling process of multiple projects managed by construction contractors (Abido & Elazouni, 2010). This problem commonly includes conflicting objectives related to the available credit limit, durations of each project and the total financing costs. The developed framework considered these objectives in a multi-objective problem for minimizing outputs. It also introduced a fuzzy based technique that is used for guiding decision makers throughout the optimization problem, for selecting among the available solutions, generated from the Pareto algorithm optimization.

Afruzi et Al (2014) introduced a method for including quality in time-cost trade-off problems. The introduction of quality was represented by different method statement each activity has, where the model also considers the change of methods for applying activities while performing optimization. This model had several objectives of minimizing the project total duration and total cost while maximizing the resulting quality. It also considered resource constraints for different methods for performing activities. This research presented a “Multi-Objective Imperialist Competitive Algorithm (MOICA)”, this algorithm operates in a method similar to genetic algorithms, where it generates empires from the available alternatives and the powerful empires increase/survive, this continues until an optimum result is reached.

An enhanced heuristic was introduced through a polynomial shifting algorithm that improves previous finance-based scheduling techniques by reducing the amount of solutions investigated before reaching an optimum result (Gajpal & Elazouni, 2015). It resulted in a reduction in the required computation time, while considering multiple projects. This algorithm introduced a concept that defines potential combinations of activities start dates, where a fewer number of combinations is generated and evaluated. It defines sets of combinations through limiting the available spectrum of solutions by considering the scheduling logic when defining these combinations. The main difference between this concept and other optimization methods, is that it does not provide the model the freedom of evaluating all available solutions, including non-feasible ones.

A multi-objective optimization model was developed for balancing projects objectives of multiple projects using Non-dominated Sorting Genetic Algorithms (NSGA) (El-Abbasy, et al., 2017). This model studies the optimization of project duration, total cost, financing cost, required cash, profit and resource fluctuations. It involves the development of three different models for scheduling, cash-flow and resource requirements. These are followed by an optimization model that analyzes projects alternatives of start times and resource utilization modes, using NSGA. Finally a fuzzy approach is used to support decision makers in selecting among different solutions considering all objectives.

2 . 5 Summary

This chapter presented a review of literature in the fields of the application of optimization techniques in the construction industry, managing multiple projects techniques, finance-based scheduling and the application of optimization techniques in multiple projects nature. Previous research mainly considered the contractor perspective while studying single or multiple projects. This means that the main funding mechanism considered was bank overdrafts or credit limits. Results-based scheduling was not considered in any of the studied research for multiple projects, as it is only offered for governments rather than contractors.

CHAPTER 3: RESULTS-BASED FINANCE

Development lending institutions are currently shifting to results-based lending to ensure the effectiveness of lent funds. This is accomplished through the main characteristic of RBF that is linking payments/disbursements to the achievement of results (Eldridge & Tekolste, 2016). RBF has been applied in various contexts through different types and levels of institutions; however, they all share the main two qualities (1) that payments are linked to the achievement of results and (2) that results and their relation to disbursements are predefined (SIDA, 2015). This challenges the focus of other traditional lending approaches of concentrating on the achievement of outputs and not results (Perakis & Savedoff, 2015). This may be explained in the difference between lending governments for building water treatment plants in traditional lending methods, while lending for connecting water to households in case of RBF, which looks for a compete water connection solution rather than specific tasks/steps.

The application of RBF mechanisms was of an interest for different types of lending and donating institutions. These institutions may include multilateral international organizations, philanthropies and bilateral development agencies (United Nations, 2003). It has been explored as one of the mechanisms that can enable these institutions in achieving their desired results and improving the welfare of people in developing countries. The verification of achieved results in developing countries commonly faces challenges related to the verification mechanisms and reliability, due to the lack of availability of data systems that can be used for investigating the effectiveness of achieved outcomes in reaching results. One of the results based finance mechanisms is performance linked payments that is applied by the World Bank and other development banks such as the AFDB (African Development Bank) (AFDB, 2017), ADB (Asian Development Bank) (ADB, 2015) and the KFW (The Reconstruction Development Institute) (KFW Development Bank, 2015), in different variations.

While KFW has been the first to adopt results-based finance among IFIs (since 2010) with a total amount of funding provided reaching EUR 735 Million (in February 2019) (KFW, 2019), the World Bank since year 2012 supported 99 operations with a total amount of nearly USD 40.3 Billion (The World Bank, 2019-A). The ADB have provided results-based finance to only 16 operations (ADB, 2019), while the AFDB only started applying results-based finance in year 2017.

In year 2012, when P4R was introduced by the WB, a limit was defined for the amount of support provided for the P4R instrument not to exceed 5% of the amounts provided using other instruments. Two years later and following the success of its application, this cap was increased to 15% over each three-year period (The World Bank, 2019-B). Following the success of P4R operations in achieving desired results and the increasing level of commitments, the WB management proposed the removal of this cap to enable the bank to satisfy the continuing need for using this instrument.

3 . 1 Program-For-Results

The International Bank for Reconstruction and Development (IBRD), one of the World Bank (WB) institutions, offers three main financing instruments namely (1) Investment Project Financing (IPF), (2) Development Policy Financing (DPF) and (3) Program-For-Results (P4R). IPF focuses on long-term social and economic development projects that provide direct support for governmental targets/projects that reduce poverty and ensure sustainable development. It provides disbursements against specific expenditures within development projects, along with providing technical assistance in borrowing countries. DPF supports borrowing countries in addressing development requirements. This is achieved by disbursing against policy and institutional reforms/actions. It is mainly focused on the strengthening of the country's general policy and institutions to ensure the sustainability of any investment efforts within the country (The World Bank, 2011).

The IBRD has been using only IPF and DPF, until year 2012 where the WB introduced Program-For-Results mechanism to fill the gap between them (Gelb & Hashmi, 2014). This gap is shown through the difference in purpose between both mechanisms, where DPF targets the development of an enabling environment for investments within the country, while IPF achieves targets that directly feed into the economic stability and prosperity of people. Targets of both mechanisms supplement each other, where a project/target that is achieved through the IPF funding requires an enabling environment formed through the institutional reform achieved using DPF. This research is focused on the analysis of the procurement strategies used within the P4R mechanism, as it was found to be the most applied results-based mechanism by IFIs.

3 . 2 Disbursement Linked Indicators

Each result area is translated into several Disbursement Linked Indicators (DLI). DLIs are the main verification method used to ensure the borrowing country is achieving valid results towards the main program objective. DLIs are considered the main building block of the P4R mechanism, as they standardize the agreement between the WB and the borrowing country. They clearly define when and how should the borrowing country receive disbursements from the WB (Zahran & Ezeldin, 2017-A). There are several types of DLIs such as:

(i) Input DLIs (I) include actions that are related to inputs of projects, such as the purchase of required materials. This type of DLI was not used in the previous operations.

(ii) Action DLIs (A) are relevant to a specific measurable action that is done by the government/implementation agency. An example of the Action DLIs is "Health centers reporting data in time" in the Health program in Ethiopia, where the government is rewarded by the bank when health centers only report the required data to the government (The World Bank, 2013).

(iii) System action (SA) are indicators that refer to a group of actions required by the government, this group of actions complement each other to form one specific goal, most commonly related to indirect result areas. An example of a system action DLI is the "Development and implementation of annual rapid facility assessment to assess readiness quality MNCH services", from the same Health program in Ethiopia. This system action includes several sub-actions that include the development of the program and its implementation, where the government is rewarded after the development and approval and scalable rewarded throughout its implementation (The World Bank, 2013).

(iv) System output (SO) are outputs that measure the performance of the government in achieving a specific output, most commonly related to indirect result areas. The "Increase of quality of high impact reproductive, child health, and nutrition interventions" is considered a SO DLI in the "Saving one million lives" program in Nigeria as it continuously measures the performance of the government towards achieving the PDO (The World Bank, 2015-C).

(v) Output (O) indicators are related to the direct outputs of the program from an action point of view. In the "Maharashtra rural water supply and sanitation program" in India one of the output DLIs is the "number of house connections to a commissioned water supply system", as it is considered a direct output from implementing the program. It also falls under the direct result areas of the program, which is the increased access to water (The World Bank, 2014).

(vi) Outcome (OO) are related to the effect of the program outputs. In the "Transformation of Agriculture sector" program in Rwanda, the "increase in daily average yields of milk per cow" is considered an outcome DLI as it represents the effect of the other outputs/efforts done through the program.

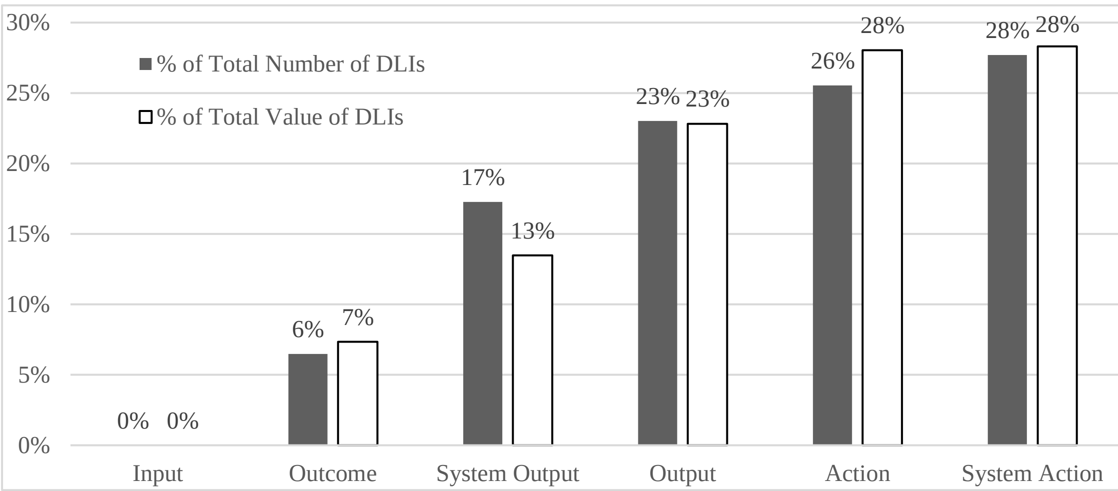

Figure 3: DLI types distribution for 35 P4R Operations (Gelb, et al., 2016)

DLIs can also be classified according to the method of disbursing their relevant amounts, as they can be disbursed at an agreed milestone (achievement of results) or can be scalable relevant to the percentage of achievement within the main target (Gelb, et al., 2016). Figure 3 shows the distribution of the types of DLIs across 35 P4R programs according to their number and values. It should be noted that action and system action DLIs are the most commonly used and have the highest share of the disbursement values.

3 . 3 Program-For-Results Application

The application of Program-For-Results funding mechanism passes through seven different stages. It starts by the borrower preparation stage where the borrower prepares a detailed proposal of the program to be submitted to the WB, then through the WB identification stage the government and the WB perform preliminary discussions about the program. During the preparation stage the WB performs detailed assessments on the program, for being used in the final negotiations made between the bank and government in the appraisal stage. According to the results/agreements made in the appraisal stage the borrowing government starts in implementing the program, achieving results and receiving disbursements until program closure and starting in returning funds. Figure 4 shows the sequence of the seven main stages for the application of P4R.

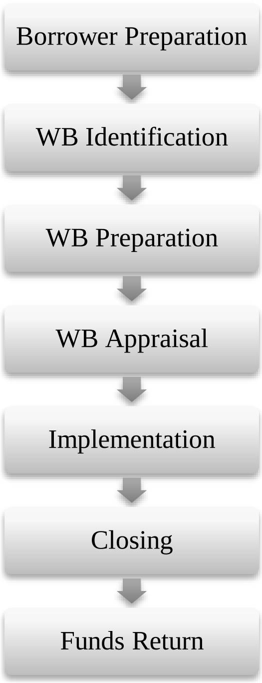

Figure 4: P4R application stages (Zahran & Ezeldin, 2016-B)

3 . 3 . 1 Borrower Preparation

The borrower preparation stage is the first stage in the P4R application process. The processes forming this stage may vary depending on the timing the country is applying. The P4R funding mechanism flexibility enables the borrowing countries to select the time at which they apply for the funding, this may be (1) before starting in the program, (2) through the initiation phase or (3) in the middle of the program. This can also be a mutual study between the World Bank and the borrowing country where the WB team may work with the government to identify and prioritize the required program for the country and the desired results. This may be through building the country's institutional capacity and strength. So the WB team will use their experience in supporting governments in making informed decisions for their development.

At this stage the government needs to identify all of the constituents of the program. These include the planning and design of projects required for offering the end products to clients/beneficiaries, preparing for any training required for the government employees, a list of the shareholders of the program, any required arrangements for the application of the program and the required funding and time schedule. One of the key tasks for the success of the program, the borrowing country is required to study the required cash flow for financing the program to assess the effect of the program financial requirements on the general budget and the required financing needs from the WB.

In case of P4R, the cash flow of the program, from the government point of view, is a common client-contractor cash flow relationship in an ordinary project, where the government plays the role of a contractor while the WB is the client. The government may or may not receive an advance payment and has continuous payments during the implementation stage, while it receives bulks of payments only when results are achieved. So the government will have an S-curve of cash out/payments and a stepped graph for cash in/disbursements from the WB. This forms a cash flow gap that has to be studied well by the government before starting in the program. Estimates of the program constituents can be based on previous similar projects/tasks or consultations with experts/companies in this field. This cash flow has to be regularly updated by the borrowing country not to affect the flow of the program or the government's budget.

The government at this stage has to start in the preparation of all preliminary assessments that are done by the WB for such programs. The WB team carries out fiduciary, technical, social and environmental assessments for each program. So, the government has to start in carrying out these assessments for checking if their program needs any modifications before submission to the WB. This may decrease the duration required for any modifications in the program during negotiations with the WB. The government may also, through the definition of the shareholders, define the key areas that it needs technical support in from the WB.

The WB published several limitations and regulations for guiding its clients on the types of programs and activities that could be covered under the P4R mechanism, so the government has to perform several assessments to ensure that its program complies with such regulations. These assessments will also guide the government in planning the program and in supporting the WB while performing the same assessments in later stages.

At the end of this stage the government representatives should be ready for submitting the proposal to the WB team. It should include (1) an identification of the overall scope of program, (2) objectives, (3) general financing requirements and (4) any other studies/assessments made the by government related to the program.

3 . 3 . 2 WB Identification

Through the identification stage, a WB task team is formed which is responsible, in this stage, to prepare the information received from the borrowing country for an initial assessment of the program that defines whether to proceed in this program or not. Figure 5 shows the flow chart of the identification process starting by the discussions between the borrower representatives and the WB to the submission of the Program Information Document (PID) to public disclosure.

Initially, the government representatives and the WB start by discussing the submitted documents to set an initial proposal which includes: (1) an initial description and assessment of the proposed program, (2) the economic and strategic impacts of the program, (3) the level of commitment the borrower has, (4) the key results and objectives of the program, (5) any required arrangements for implementation, (6) an analysis for the overall performance of the borrowing country with the WB through other operations and (7) the financial obligations on the WB and their timing.

If a preliminary agreement is reached at this stage, then the WB sets a budget for the program preparation process and a WB task team is allocated for the program. This task team has a team leader and other members of specialists/experts relevant to the program sector. Once the task team is formed, it starts in some preliminary tasks, (1) the definition of the parameters of the program and assessment of its rationale, strategic relevance, development objectives and its relation to relevant Country Partnership Strategy (CPS), Country Assistance Strategy (CAS) or any other similar instruments, (2) in case if the program is in progress, the task team checks its current status/performance and suggest any corrective actions based on previous experience in similar programs, (3) start in the identification of the required results and any arrangements for the design and implementation processes, (4) discussing with the borrower's representatives alternatives for financing the program, (5) check compliance of the program systems with the fiduciary, social and environmental and governance rules of the WB and (6) perform a preliminary risk assessment for the program.

Following the development of the program concept and financial coordination between the WB and its development partners, the task team issues its Program Concept Note (PCN), which includes all information concluded from its preliminary tasks and an Initial Program Information Document (PID) that sums up the main program elements and the proposed financing offered by the bank. Both the PID and the PCN are submitted for concept review by another committee within the WB, depending on the conditions mentioned in the Guidelines and Procedure for Corporate Review of Operations and Country Strategies. Through the concept review, the reviewing committee decides whether to proceed with the program preparation or not. If yes, then it decides upon the parameters for assessments carried out, any future reviews by the bank and the resource needs and time schedule required for the preparation of the program. Once the program passes the concept review, the task team presents the PID for public disclosure.

After the government submits its proposal, the WB performs preliminary discussions with the borrowing government for setting (1) a preliminary description and assessment of the program, (2) its strategic and economic impact, (3) the borrower's level of commitment to the program, (4) the key program objectives and results, (5) any required implementation arrangements, (6) a review of the history of the relationship between the WB and the borrowing country and (7) a time schedule of the cash flow requirements by the WB. These preliminary discussions may pass the program as submitted, make some modifications to the program or even guide the borrowing government to a more suitable funding mechanism.

Once a preliminary agreement is reached, the WB starts allocating a task team for the program. This team is responsible for managing communications between the borrowing government representatives and the WB management. The task team is responsible, through the identification stage, to perform some preliminary tasks that include (1) the definition of program parameters, its rationale, development objectives, strategic relevance, relation to the Country Partnership Strategy (CPS) and Country Assistance Strategy (CAS), (2) check the current status of the program, if it is a running program, (3) identify program results and required arrangements for the design and implementation processes, (4) discuss any alternatives within the program scope with the borrower, (5) perform a preliminary risk assessment for the program and (6) confirm the program complies with governance, fiduciary, social and environmental rules and regulations of the WB. The results of these tasks are presented in two documents called the Program Concept Note (PCN) and Initial Program Information Document (PID), which are submitted for concept review within the WB. Once the program passes the concept review, the task team proceeds to the preparation stage.

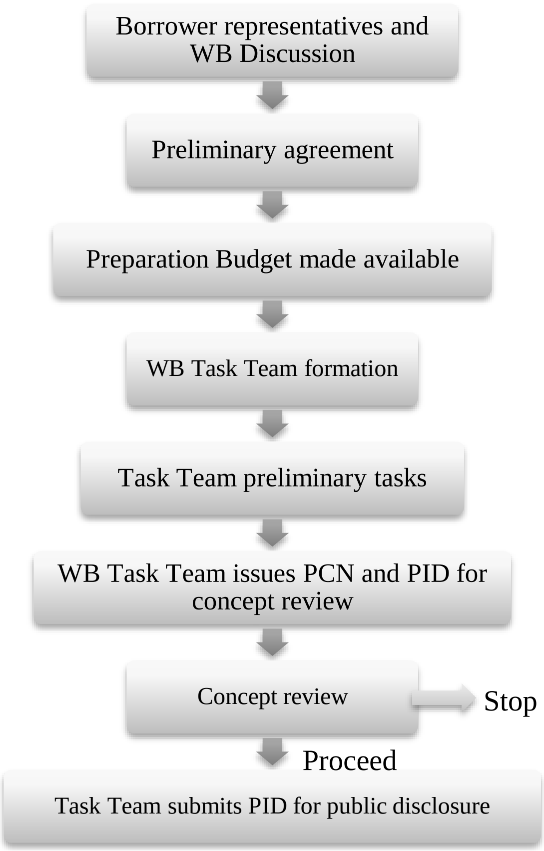

Figure 5: Identification stage flow chart

3 . 3 . 3 WB preparation

The WB task team conducts detailed assessments of the program for setting the main guidelines for future negotiations with the government. These assessments include a (1) detailed technical assessment of the program, which studies the relation between the program objective and the country development objective, the economic justification of the program, the definition of results, their measurement criteria, the expenditure structure of the program, the monitoring criteria of program results, an assessment of the current status of the program sector, an analysis of the results framework and the link between bank disbursement and results achievement, ensuring that program funds are used appropriately and oriented towards program objectives. (2) A fiduciary assessment of the program, which assesses the fiduciary systems of the program/borrower against the Bank's Operations policy "OP/BP 9.00 Program-For-results Financing". It reviews any rules and regulations within the country related to the program financial requirements, it also reviews the capacity of implementing agencies and government institutions for suggesting any required capacity building and strengthening that supports program implementation and sustainability. (3) Environmental and social assessment of the program to check for any environmental or social effects of the program on the country. It also checks the compliance of the program with the WB environmental and social safeguards policies. (4) Risk assessment of the program, which builds on previous assessments to define the main risks that should be considered within the program, following the definition of such risks, risks are assessed, and mitigation measures are identified for being included in the program. Based on the overall risk assessment of the program, management decides whether to proceed in program preparation or not. This risk assessment is continuously updated and monitored throughout the program preparation and implementation stages (The World Bank, 2012).

Results of these assessments enable the task team to direct the program through one of the following options (1) if the program is agreed and results of all assessments are acceptable then the program proceeds in the preparation process, (2) if the program has severe weaknesses then the program is either rejected or an alternative funding mechanism is suggested and (3) if the program has minor weaknesses, according to these assessments, then key program improvements are set and then proceeds in the preparation process.

After resolving all issues related to the assessments carried out, then the task team issues several documents for the Management Decision Review meeting. These documents are the Draft Project Appraisal Document (PAD), the updated draft Project Information Document (PID) and the draft legal agreements. The review meeting is responsible for (1) reviewing the outputs of the assessments carried out, (2) checking the adequacy of DLIs and related verification methods, (3) reviewing program overall risk assessment, (4) deciding if any of the activities within this program is not covered by the Bank Policy, (5) reviewing the conditions set for the program related to appraisal, negotiation, board presentation and other legal conditions, (6) reviewing and assessing any support offered by the WB through the implementation process and (7) finally decide whether the task team continues in the appraisal process or not. If the program passes this stage then the PAD, PID and draft legal agreements are moved forward to the appraisal stage.

3 . 3 . 4 WB Appraisal

The appraisal stage is considered the final stage before implementation. It is responsible for setting the agreement on the approved program, by the management review, between the WB and the borrowing country. The appraisal process starts by the submission of the task team of a request to negotiate program financing to the management. Once negotiation is authorized, the Bank, Borrower and any other related third party start in the negotiation process.

Through the negotiation stage, any new major issues occurring, that affect the program design or financing, have to be recorded and reported by the task team to the bank board for approval. Once an approval is received from the board, then the negotiation cycle is repeated until a final agreement is reached. The final agreement between all parties includes:

1. A fully detailed scope and objectives of the program

2. The required results from the program

3. The program specific legal terms and conditions

4. DLIs, amounts disbursed and any related provisions that may affect disbursements, commonly DLIs are first proposed by the borrowing country and then agreed by the WB

5. The verification mechanism and allocated Independent Verification Agent (IVA)

6. Any required strengthening measures for the borrowing country's institutions

7. The results of assessments done by the WB and any required modifications for the program

8. The implementation strategy and mechanisms

Generally, governments are more concerned with DLIs and IVAs. DLIs are considered the main outcomes of the program. DLIs have to measurable, auditable and very specific. This can be finishing a pumping station in a water supply program or a higher number of educated children in a child education program. Governments have to carefully select the DLIs they would like to be disbursed for. As this affects their cash flow throughout the program. The IVA is the entity that verifies that results that were agreed and set as DLIs were achieved/reached for the government to get rewarded. This IVA has to be a third party which is not related to any of the other parties, not to make biased decisions.

Following the agreement, the executive directors consider financing the proposed program at a Board meeting. Then the final PAD is disclosed after being submitted to the Policy and Operations Unit of the Secretariat (SECPO). Later, a Program Action Plan (PAP) is prepared. This action plan is required to set all actions required by the WB for supporting the borrowing country and any other measures agreed before. Before signing a legal agreement to mark the start of the program implementation, all of the resulting documents and studies are presented to corporate oversight units to check for any fraud or corruption cases within the program.

3 . 3 . 5 Implementation

The implementation stage starts by applying initial strengthening and capacity building requirements that are agreed during previous stages, then the advance payment is paid to the government, if any, then the implementation process starts. The borrowing government starts in the implementation of the program through implementing agencies. Once a DLI is achieved, the Independent Verification Agent (IVA), previously agreed, reports the verified results to the WB. In case the results are totally met and approved the task team informs the borrower of the bank decision and the government submits electronically a disbursement request. If the DLI is partially met and if scaling is agreed, the WB determines the amounts to be disbursed and informs the borrower of them for being submitted electronically. Concurrently, the WB performs (1) financial statements audits, (2) technical reviews/audits, (3) provides implementation support and (4) check any needs for additional financing or restructuring. Any resulting actions or modifications have to be approved by the WB then a modified PAP and DLI matrix is issued and agreed with the government to be considered in the implementation process. In the middle of the implementation process, the WB performs a midterm review and restructuring where it examines the status of the program and investigates any need for restructuring or suggested changes for the improvement of the program implementation process or outputs. Figure 6 shows the flow chart of the implementation stage.

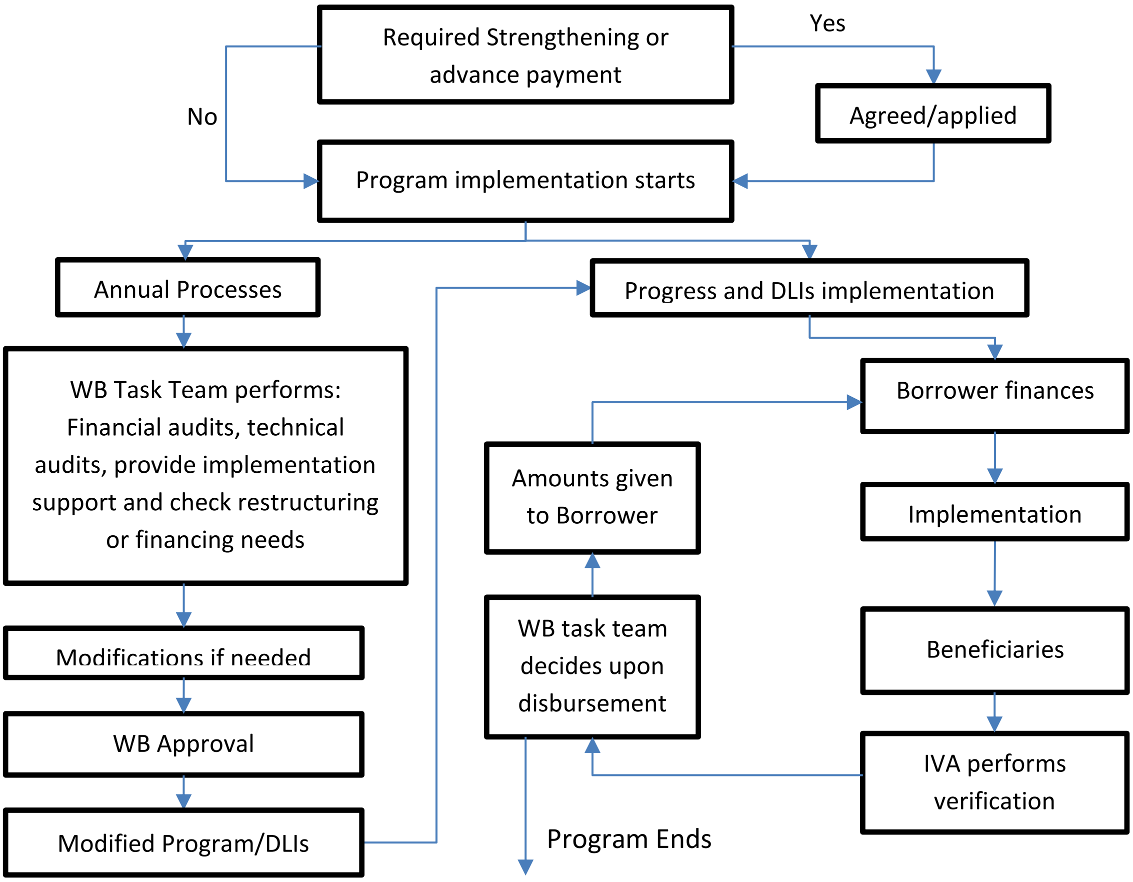

Figure 6: WB Implementation procedures

3 . 3 . 6 Closing

At the end of the program the WB task team has to check that the amounts disbursed are less than or equal to the government expenditures on the program. Following the pre-agreed closing date, if there was no extension of time approved, the WB closes the program financing account and any undisbursed amounts are cancelled. Finally, the WB task team prepares the Implementation Completion and Results report (ICR). The ICR report summarizes the overall performance of the borrowing country in the program through comparing results to originally agreed objectives and DLIs. It also presents the feedback of the borrower concerning the program and the P4R mechanism.

3 . 3 . 7 Funds Return

At this stage the full amounts borrowed by the country are returned to the WB according to the agreed mechanism. The total amounts borrowed are previously settled during the closing stage. This means that after the program ends or after a total amount is agreed, this amount is equivalent to the uniform amount set for installments after applying the interest rate percentage, according to an agreed amortization schedule.

3 . 4 Program-For-Results WB Fees

This section describes fees that the WB charges borrowers when applying P4R mechanism; however, these fees are charged by other lending institutions in case of RBF. In case of results-based finance, governments are charged fees similar to lines of credit, called commitment fees, while Interest calculations and other fees are calculated differently. Interest rates and loan repayment periods are also different. IFIs commonly charge a much lower interest rate and offer higher loan repayment periods, as a means of support for developing/borrowing countries. Banks offering results-based financing consider results as final benefits from the developed projects and not interim financial requirements/payments. This means that a government would finance projects until they deliver their desired results and that is when lending institutions make disbursements. Such agreements commonly involve activities that may not be related to the end results; however, they are essential for the sustainability of the developed projects.

The WB charges borrowing countries several fees such as (1) front-end fee, which is a percentage of the total loan amount paid within 60 days of the loan agreement, this fee may be deducted from the loan amount or paid by the government, (2) commitment fees, which is calculated as a percentage of the undisbursed balance of the loan amount, as a reward for the Banks' commitment for setting the agreed amounts ready for the borrowing country whenever required and also an incentive to encourage the borrowing country make earlier disbursements by achieving results earlier and (3) interest, an agreed percentage that consists of a spread over the London Inter-Bank Offered Rate (LIBOR) (The World Bank, 2011). Interest amounts and repayment durations are calculated in two different methods (1) commitment-linked repayment schedule: this means that the interest calculation period starts from the date of commitment between the bank and borrower and (2) disbursement-linked repayment schedule, which only calculates the interest duration between the date of making disbursements to return date.

In this case, governments have to maintain the balance between satisfying cash flow requirements, decreasing inflation that escalates costs of any delayed projects, decreasing commitment fees paid on undisbursed amounts, decreasing interest rates calculated on early disbursements and decreasing cash flow gaps for decreasing burden on government's general budget.

Managing this type of programs, several parameters have to be balanced to result in an optimum spending on the program. These parameters are:

(1) The inflation rate: an inflation rate is added to the total cost of projects based on their start date. This is based on the assumption that the costs of projects are based on market rates at the start data of the program, so they only include inflation to the midpoint of construction, of that specific project. This means that the more a

project is pushed forward/delayed, the higher inflation is compounded on it. This makes projects tend to start earlier.

(2) Commitment fee: the commitment fee is calculated on the total undisbursed balance. This fee is intended to encourage borrowing countries to make disbursements as early as possible. It is considered a charge for compensating the WB for its commitment to make the agreed amounts available for the borrowing country, whenever required. This fee is considered an unnecessary burden on the government as it is paid for amounts that do not generate any benefit/income for the country (unlike the interest percentage), so governments will not prefer paying it. This makes it preferable to start in projects as early as possible.

(3) Interest rate: in case of P4R, an interest is calculated on amounts disbursed by the bank to the borrower for the duration from time of disbursement to the payment date. This means that the lower this duration is, a lower interest is paid. This makes it preferable to start in projects as late as possible.

(4) Maximum expenditure: the overall expenditure of the government on the program is the difference between cumulative cash in (disbursements from the bank) and cumulative cash out (spending/transfers to implementing agencies). For decreasing the maximum spending on the program, the number of projects running simultaneously has to be decreased, so projects tend to be moved apart from each other not to build higher cash flow gaps.

Figure 7 describes the effect of each parameter on the scheduling process. For example, to minimize the inflation rate added on the total price of each project makes it preferable to start in projects as early as possible, same applies to the commitment fees. While to minimize the amount of interest paid on the total price of projects, they are required to start as late as possible. On the other hand, to decrease the overall spending of the borrower on multiple projects, it is preferred to spread out projects to obtain the least possible overall cash-out at each point of time.

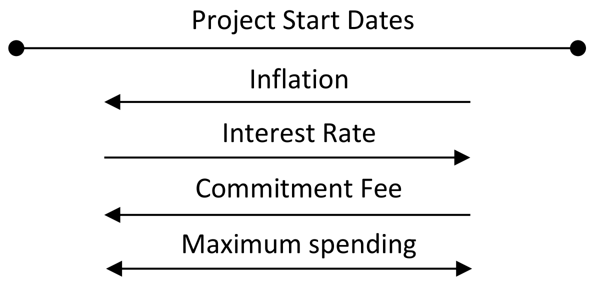

Figure 7: P4R scheduling parameters

Scheduling multiple projects, while considering these constraints, requires extensive analysis of each project while considering the overall standing of the program. According to literature, research addressed problems of this nature, but from a contracting company's perspective. This reflects on (1) the consideration of credit limits for financing multiple projects, (2) fixing prices of projects (not adding inflation on project prices, (3) the form of repayment of borrowed amounts, where contractors repay banks through monthly invoices received from their clients while RBF borrowers repay banks in the form of installments at an agreed date following the end of program and (4) the main target of contractors is to reduce the effect of the financing cost on their profit while in case of RBF the main target changes to become increasing the benefit from received financing.

3 . 5 Program-For-Results Risk Assessment

One of the main assessments performed by the WB during the preparation stage, is the risk assessment. In year 2012, when P4R was newly introduced, an Integrated Risk Assessment (IRA) method was introduced to analyze any risks that may affect the achievement of the program development objective or results. This risk assessment method is initiated in the preparation stage and is continuously updated until the closing stage to include the effect of any events that may occur during the planning and implementation of the program (Ezeldin & Moussa, 2017).

The risk management process performed by the WB includes four different stages, (1) risk identification, through previous experiences with the borrowing country on similar projects/programs and through consultations with borrowing government representatives, (2) risk assessment, through the distribution of risk surveys among WB task team and other parties related to the program, which results into the classification of the importance of each risk factor according to its effect on the program development objective, (3) risk response, which involves the identification of risk mitigation measures for each risk factor and (4) risk monitoring and reporting which takes place throughout the P4R application process. It should be noted that the overall assessment of programs does not depend on the overall ratings of risk categories; however, it is based on the overall judgement of WB professionals on the program.

3 . 5 . 1 Integrated Risk Assessment

Under the Integrated Risk Assessment method, risks are identified through four different categories, (1) technical risks, that are related to the program technical design, its technical soundness, number and diversity of components and flexibility of its design, (2) fiduciary risks, any fiduciary aspects that may affect the program, including risks related to the institutional capacity of the implementing agencies responsible for the program application and sustainability, (3) Environmental and Social (E&S) risks, these include any social or environmental risks/consequences caused by the program on the country directly or indirectly or E&S effects throughout the program that may prevent the achievement of its development objective and (4) Disbursement Linked

Indicators risks, these include any risks that may affect the achievement of DLIs in time and according to the agreed standards (The World Bank, 2011)

3 . 5 . 2 Systematic Operations Risk Rating Tool

In year 2014, the WB introduced a harmonized risk assessment method called the Systematic Operations Risk Rating Tool (SORT) to replace any other risk assessment method applied on all of the WB funding methods. The main difference between the IRA and SORT is that the SORT provides more classifications for types of risks. SORT classifies risks into nine different categories, (1) political and governance, this includes any risks caused by the political situation within the country and its governance setting. The selection of such risks has to be relevant to the program objective and results. (2) Macroeconomic risks, these include domestic and external economic risks affecting program results. These may stem from the quality of economic policies in the country and strength of the economic/financial institutions. The consistency of the program with government's policies and development goals. (3) sector strategies and policies, this type of risks includes any risks caused by institutions within the sector of the program and their effect on the program objective. (4) technical risks, similar to the same category from the IRA. (5) Institutional capacity for implementation sustainability risks, this are risks that may affect the sustainability of the program outputs caused by an insufficient capacity of the government institutions responsible for operating and maintaining program results. (6) Fiduciary risks and (7) Environmental and social risks are similar to the risks falling under the same categories in the IRA. (8) Stakeholders risks, these risks are related to stakeholders involved in the implementation, design or objective. (9) other risks, this risk category covers any other risks that do not fall under any other category mentioned before or it may be left blank

(The World Bank, 2014). This assessment method provides a better structure for evaluating risks affecting programs due to the diversity of the risk categories included.

3 . 6 Summary

This chapter discussed the results-based lending mechanisms offered by international financial institutions. It provided a detailed review of the Program-For-Results mechanism, as one of the well-established results-based mechanisms offered by International financial institutions. It started by presenting fees added by the WB on amounts lent to borrowing governments in case of P4R financing. Later, it provided a detailed review of the types of DLIs set within P4R Programs. It also made a detailed explanation of the steps required by the WB for applying P4R mechanism, starting from the identification stage up to the return of the borrowed amounts through installments. Finally, this chapter explained in detail the processes of risk assessment essential for the application of P4R. Processes and mechanisms presented in this chapter can be applied to other RBF mechanisms offered for lenders as they all share the same stages for setting a successful RBF plan. This has to start by a proposal by the borrower, then negotiation rounds between the borrower and lending institution and finally reaching an agreement. Then program execution and financial transfers regulation, while having a third-party for ensuring results are achieved. This continues to the closing stage and lessons learned.

CHAPTER 4: RESEARCH METHODOLOGY AND MODEL DEVELOPMENT

This chapter explains the methodology followed to achieve the research objectives. It describes steps followed starting from the review of literature to the validation of the developed model. It then describes in detail the developed model and the integrated tools and techniques. The model development section focuses on the borrower preparation stage as this is when the borrower has the highest flexibility in setting program details. Later stages within results-based mechanisms can be integrated into the model as additional activities, projects or constraints. Processes described within this chapter may follow the WB regulations; however, then can apply to any other RBF financed program as they share the same overall concepts.

4 . 1 Research Methodology and Proposed Approach

This research is divided into seven main stages, as shown in Figure 8. It was initiated by a review of literature related to the finance of mega infrastructure programs, This included a review of International Financial Institutions and their available funding mechanisms (Zahran & Ezeldin, 2016-A). This review then focused on available techniques/mechanisms for results-based lending. Program-For-Results funding mechanism was considered as an example of these mechanisms. A review of literature published by the World Bank and other development partners was performed on the Program-For-Results mechanism and its required tools and techniques (Zahran & Ezeldin, 2016-B)(Zahran & Ezeldin, 2017-A). Further review was performed on the management mechanisms required for managing this type of programs/multiple projects. This included a review of Multiple-Projects-Management mechanisms, time-cost tradeoff mechanisms, finance-based scheduling techniques and optimization processes.

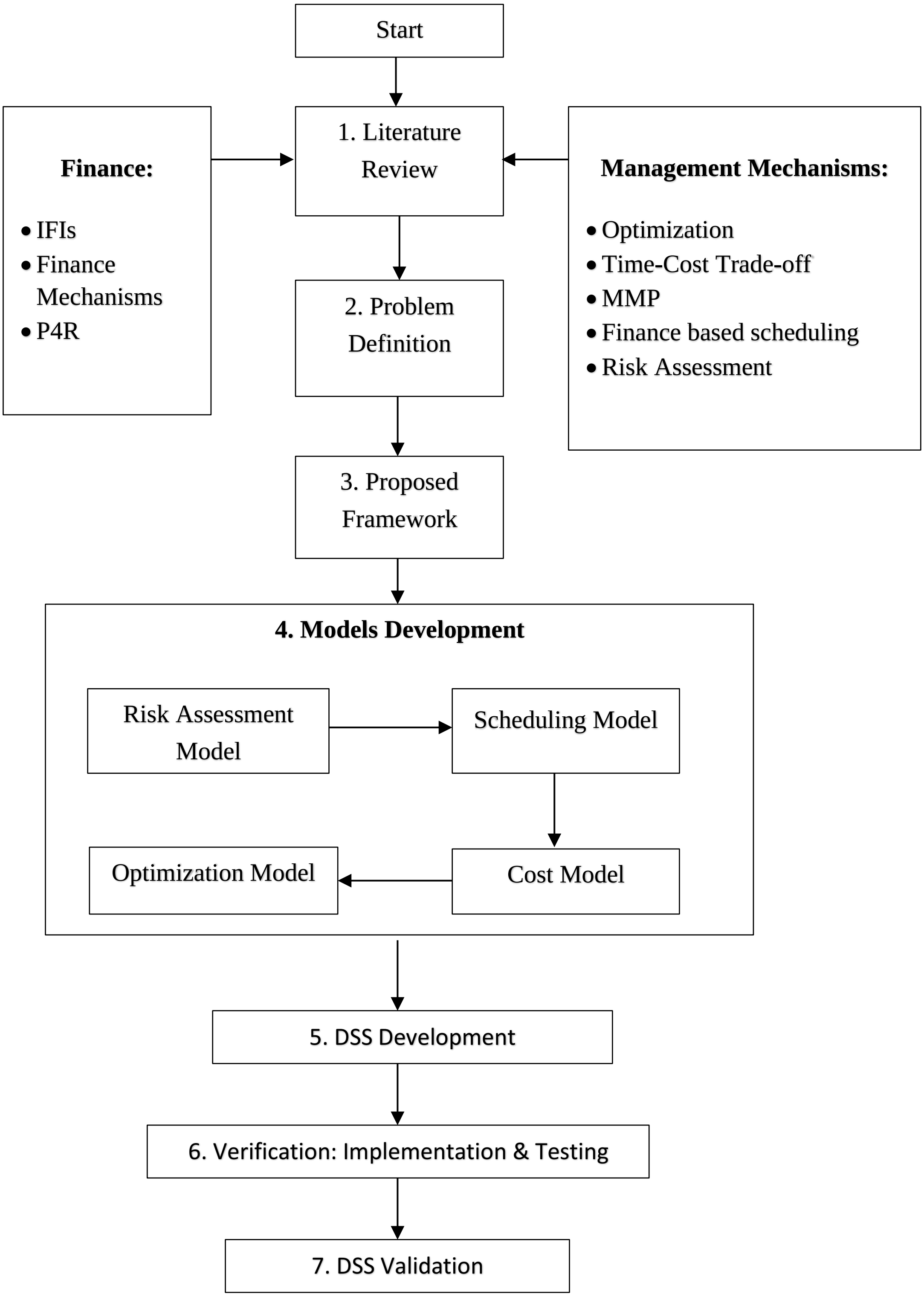

Figure 8: Research Methodology Detailed Flow Chart

This led to the definition of the main problem behind this research. For solving such problem, a framework was proposed for supporting governments in applying the results-based finance mechanism (Zahran & Ezeldin, 2017-A). Four main models were developed, (1) the risk assessment model and (2) scheduling simulation model, (3) cost simulation model and (4) optimization model. These models were then integrated into a user-friendly decision support system that guides the government throughout the P4R processes, from initiation to program closing. This DSS is then implemented on a case study, for testing its capabilities (verification). The proposed approach and model are then validated using the Sustainable Rural Sanitation Services Program in Egypt.

4 . 1 . 1 Literature Review and Problem Definition

A review of literature was conducted to diagnose different tools and techniques required for the application of results-based funding mechanisms. The Program-for-Results mechanism offered by the World Bank was considered as an example for these mechanisms. A review of previous and in pipeline operations was performed to summarize any lessons learned and best practices required for supporting future applications of P4R. It was found that the application of RBF/P4R requires extensive studies and analysis for programs, compared to other funding mechanisms. It was also concluded that managing these types of programs requires the application of Multiple-Projects-Management techniques. A review of previous research in this field was conducted and it was found that finance-based scheduling/optimization was applied in different variations of multiple-projects/programs; however, results-based funding was not considered. In addition, most of the conducted research was performed from a contractor perspective and did not consider a client/government perspective.

In case of P4R, This is translated into the three stages prior to implementation (Identification, Preparation and Appraisal). These stages involve different types of studies and different rounds of negotiations performed by all stakeholders. These studies and negotiations are considered continuous drivers for making changes to originally designed programs.

A Two-Year-Review report was issued by the WB to summarize lessons learned and suggest any changes to the proposed P4R framework. This report covered eight programs that were approved by the WB at that time (The World Bank, 2015-B). One of the main tasks performed under this report, is the execution of structured interviews with senior bank managers, government officials and development partners. These interviews generally showed the interest of bank clients and development partners in the P4R mechanism. It also indicated that borrowing countries preferred IPF over P4R, based on their previous experiences in IPF, over the application of a newly developed mechanism, like P4R.

This introduced the need for a tool/mechanism that supports borrowers throughout the stages required for applying P4R. It would also provide borrowing countries the required knowledge/support for applying this new tool based on WB definitions and the integration of lessons learned from previous operations. The P4R mechanism, unlike IPF that is a straightforward borrower-lender relationship, requires extensive analysis and planning of the supported program and cash flow. These studies also reflect on the decision of borrowing entities when selecting among funding mechanisms. A tool that simulates development programs would support borrowers in selecting P4R and achieving its main goal of realizing development goals while maintaining their enabling environment. It would also enable the borrowing entities visualize its financial requirements/status throughout the program life cycle.

One of the main challenges in simulating the P4R programs, is the management of its sub-projects and sub-tasks simultaneously. This would require the management of several activities of different nature and financial requirements while considering the main source of funding, which is the achievement of DLIs for getting disbursements. Generally, in P4R financial planning, the WB commonly distributes amounts for each DLI according to its importance and not the cost of its achievement. For example, the DLI set for the execution of an expensive project (mega project) may be nearly equal to the DLI set for the draft of a law that maintains the sustainability of such project. This means that the borrowing entity has to plan its program, while considering cash flow gaps and pushing easily achievable tasks/activities towards dates that have shortages in cash flow. Borrowers may also consider the amounts of interest paid for receiving DLI amounts earlier, so they would look for a near optimum plan of maintaining the lowest cash flow gap while having to repay the lowest amount of interest. Other loan fees may also be considered for maintaining the lowest amount of added costs on the borrowed amounts. These include commitment fees calculated on undisbursed amounts and inflation rate added on projects costs, if delayed, or according to their planned dates.

4 . 1 . 2 Proposed Framework

Through issues presented in the previous section, a framework of a decision support system is proposed to guide borrowers through all stages of the application of RBF mechanism. This DSS follows the WB definition of RBF processes, but from the borrower's viewpoint. It enables the borrowing entity to make informed decisions and evaluate its position at each stage of discussions/negotiations before setting the program. It also guides borrowers in managing institutions and implementing agencies through the implementation process. This DSS mainly depends on the WB processes of P4R along with a summary of previous experiences in P4R programs. This is due to the availability of a detailed guide for the RBF mechanism offered by the WB; however, this framework can be applied to any other RBF mechanisms.

Figure 9 shows the main framework of the DSS. Once the borrowing entity has a full understanding of the program contents, it starts in the borrower preparation stage by performing some general assessments on the program, that show whether to proceed in applying for the P4R financing or find a more suitable mechanism, based on the WB rules and regulations for P4R supported operations. If the program passes these assessments, the borrowing entity proceeds to the technical, fiduciary, environmental & social and risk assessments. The main role of the DSS is to guide the borrowing entity on the main contents of such assessments, due to their case by case nature. Except for the risk assessment which guides the borrowing entity through the stages of risk assessment, based on previous experiences in P4R operations and the WB definition of risk assessment processes. After performing such assessments and taking their results into consideration while revising program contents, their schedules and costs, the borrowing entity proceeds to the scheduling, cash flow and optimization modules. These modules are responsible for preparing a detailed time schedule of the program, calculating its overall cash flow and performing cost and time optimization for providing a near optimum solution for program parameters. These two modules form the main building block of the framework, where all later processes use them for updating the optimized schedule and cash flow.

After finishing all assessments, scheduling and cash flow calculations, they are included in the proposal submitted to the WB. Through the identification stage, the framework supports the borrowing entity throughout discussions held with the WB. Any updates or concerns resulting from the discussion are continuously included in the assessments and optimization modules for having informed supporting data targeting near optimum goals. This loop of discussions and assessments and optimization update continues until results of preliminary discussions are agreed, and the program proceeds to the preparation stage. At this stage, the WB performs assessments on the program while consulting with the borrowing entity. The borrowing entity uses the outputs of the assessments and optimization modules in supporting the WB task team and also updates these modules based on the outputs of the WB assessments, to include any recommendations, new activities, milestones, changes to cash flow profile or any other recommended changes.

After passing the WB management review, the program proceeds to the appraisal stage, where final negotiations between the WB and the borrowing entity are held. Any outputs or recommendations resulting from negotiations are continuously applied in the assessment and optimization modules, for updating the near optimum target of the borrowing entity until program parameters are agreed and the program proceeds to the implementation stage. The framework then supports the borrowing entity in three different ways, where it (1) provides a detailed framework for the management and follow-up of implementing agencies and continuously updating assessments and schedules according to program updates, (2) provides the borrowing entity a supporting tool for any negotiations made with the WB based on the results of the WB audits and reviews during the implementation stage and (3) provides the borrowing entity a tool for re-discussing the program with the WB following the midterm review and restructuring, if required. Then the framework summarizes for the borrowing entity the amounts received from the WB and the amounts spent on supported activities for obtaining an overall standing for the program to be used for final settlement of the program financing and account closure with the WB and preparing for returning funds to the WB according to the agreed schedule.

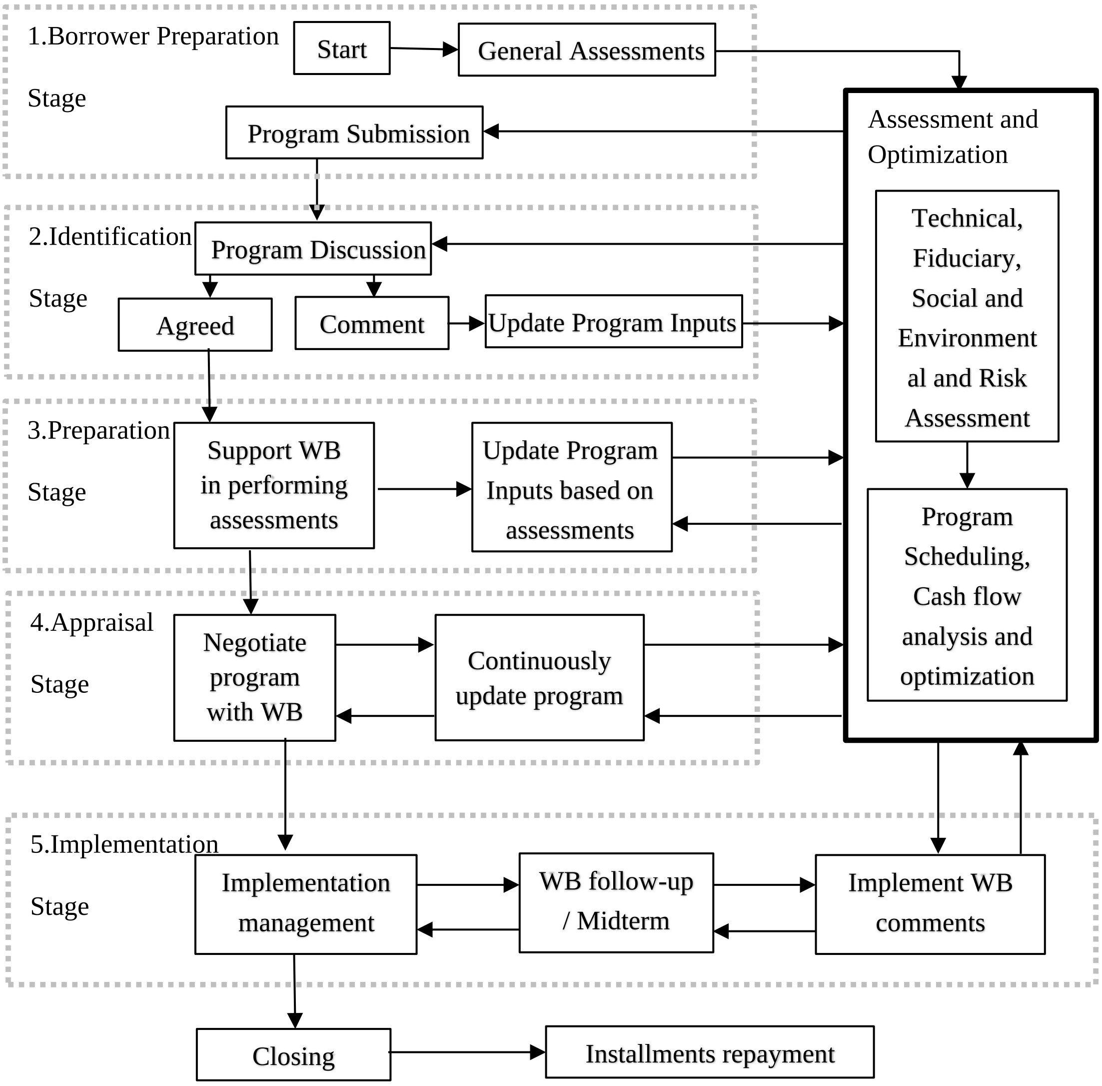

Figure 9: Proposed Framework

4 . 1 . 3 Models Development

The main building block of the DSS includes two main models, which are the (1) risk assessment model and the (2) cost and schedule simulation and optimization model. These two models are required to be continuously used by the DSS user throughout the lifetime of the P4R application, so they are required to be user friendly and provide the user with necessary information for performing negotiations or during implementation.

4 . 1 . 3 . 1 Risk Assessment Model

This model is developed using Microsoft Excel and VBA to Excel. It consists of four main modules. The first module is the introduction module which directs the user through the risk assessment processes. The second module is the risk rating survey, which provides the user with the format of the risk survey. This risk survey is editable as it only includes general most common risks obtained from previous operations, so users can add risks specific for their programs. The third module is the risk analysis module, which obtains survey results from the users and translates them into risk rating for each risk. Results of the risk analysis is presented in the risk survey results module, which presents the list of possible risks ranked according to their severities.

The definition of the P4R risk management processes involved three main stages, including (1) the identification of the main risks affecting P4R supported programs based on previous operations and the guidelines offered by the WB for SORT, (2) defining the main mitigation measures previously defined/applied in previous operations for each risk, (3) developing a framework/prototype for supporting governments in the process of risk management of P4R while following the WB guidelines to be used in WB consultations. This process follows the structures of both IRA and SORT in defining risk categories, as it is intended to support the government in defining program risks from its own point of view and use this risk assessment in guiding the WB risk assessment. The methodology adopted consists of four consecutive steps; namely (1) risk identification, (2) risk assessment, (3) risk response and (4) risk monitoring.

4 . 1 . 3 . 1 . 1 Risk Identification

A review of the 60 previous and in-pipeline operations supported by the WB through P4R mechanism and a review of the WB guideline for SORT and IRA resulted into the definition of the main risks that are commonly considered in P4R operations. The below tables show the main risks covered under each category.

Table 4: Program-For-Results Common Risks

1	**Political and Governance Risks**
1.01	Political stability in the country/government
1.02	Legislation changes
1.03	Upcoming political events
1.04	Government corruption
1.05	Development objectives are unclear
1.06	Required political decisions/laws are not yet agreed
1.07	Government has low levels of transparency, accountability and participation
1.08	Operation may lead to political instability

2	**Macroeconomic Risks**
2.01	Fiscal Deficit
2.02	Foreign currency (Shortage)
2.03	Currency Exchange rate
2.04	Inflation rate
2.05	Macroeconomic stability in the country
2.06	Debt to GDP ratio
2.07	expected economic shocks/events
2.08	Strength of macroeconomic institutions
2.09	Inadequate intergovernmental transfers

3	**Sector Strategies and Policies Risks**
3.01	Availability of baseline data
3.02	Government commitment to sector
3.03	Sustainability of sector strategies
3.04	adequacy of sector funding
3.05	Adequacy of sector strategies/policies

4	**Technical design of project or program**
4.01	Monitoring and evaluation capacity
4.02	Technical Soundness of program activities
4.03	Awareness of the government of technology
4.04	Availability of enabling environment

4.05	Relation between program objective and government development objective
4.06	Technical complexity of the program design
4.07	Number of components in the program
4.08	Program planning accuracy

5	**Institutional Capacity for implementation**
5.01	Government capability of implementing program
5.02	government capable of sustaining the continuity of program
5.03	Previous experiences in P4R for the government
5.04	Previous experiences with the World Bank
5.05	Experience of the implementing agencies in program
5.06	complexity of implementation arrangements
5.07	Staff access to training
5.08	Capability of implementing agencies of handling program
5.09	Fraud and corruption in implementation agencies
5.10	Availability of financial and human resource capacity for program sustainability

6	**Fiduciary Risks**
6.01	Country follows bank fiduciary requirements
6.02	Government follows financial reporting requirements
6.03	Government applies an auditing system for financial reports
6.04	Adequacy of fiduciary systems for program management
6.05	Funds flow to program/project
6.06	Adequacy of procurement capacity of participating/implementing entities
6.07	Support received from other funders/Banks/Creditors
6.08	Market conditions
6.09	Inefficient use of funds
6.10	Contracts commonly exceed their value and schedule
6.11	delayed payments to contractors

7	**Environmental and Social Risks**
7.01	Any Land Acquisitions required
7.02	Public opposition for the program
7.03	Government enforcement for WB rules for environment
7.04	Consistency of government environmental rules with WB rules
7.05	Any Environmental Impacts for the program
7.06	Adverse Natural disasters/events may be caused
7.07	Effects of program on people

8	**Stakeholders Risks**
8.01	Stakeholders support for the development objective
8.02	Stakeholders support for program activities
8.03	number of stakeholders
8.04	Relationship between stakeholders
8.05	Effect of program on stakeholders

8.06	Public understanding of the program

9	**DLIs risks**
9.01	Not/Late achieving DLIs
9.02	Delays in Verification (by IVA)
9.03	Inadequacy of DLIs for PDO
9.04	Implementing agencies access to finance

4 . 1 . 3 . 1 . 2 Risk Assessment

The risk assessment process requires the distribution of risk surveys among the program stakeholders. This is due to the different nature of each program and its relevant risks. Surveys distributed among experts will request them to rate the probability each risk may take place and its impact. Experts will select between one of the five categories (1) N/A, (2) Low, (3) Moderate, (4) Substantial and (5) high.

After getting results from surveys, probabilities and impact ratings are converted into numbers (a scale of zero to 4), then each is multiplied by the number of times selected by a survey respondent to get the overall probability and overall impact. Then the overall severity of the risk is calculated by multiplying both probability and impact. These severities are then used to categorize risks, with the most severe risks in the top to be presented to the user.

4 . 1 . 3 . 1 . 3 Risk response

Based on the ranking of severities, the model will propose the most important mitigation actions. Each risk category and its common mitigation method are linked using the same code, so a mitigation method of a risk having a high severity is presented to the government as a priority for the program.

4 . 1 . 3 . 1 . 4 Risk monitoring

The model can also be used to continuously monitor the risk assessment throughout the P4R preparation process up to the program implementation. This is done through the continuous update of the risk surveys and inclusion or exclusion of any risks that may occur during the program implementation.

This model is considered a predecessor task for the program simulation model as it most commonly affects the program contents. Mitigation measures commonly include added activities/tasks to be performed by the borrowing entity for covering unavoidable risks or for adapting to the requirements of the WB. Risk assessment may also exclude some activities from the program contents covered by the WB, which affects the cash flow of the program.

4 . 1 . 3 . 2 Cost and Schedule Simulation and Optimization Model

This model was developed using Microsoft Excel as a spreadsheet modeling tool, Microsoft Visual Basic Applications (VBA) as a programming tool to handle the user-interface phase efficiently and Evolver Add-in to Excel as an optimization tool. As shown in Figure 10, This model consists of five modules, distributed over two segments. The two main segments are (1) the user interface segment, which is responsible for the management of data input processes and the presentation of final model outputs back to the user and (2) the processing segment, which is responsible for using input data for scheduling the program, calculating overall costs and running the optimization process.

The first module is the input module which sorts all data input by the user into a database format for facilitating data handling in the model. The second module is the scheduling module which simulates the time schedule of the program according to user inputs. The third module is the cost module which simulates the cash flow of the program according to input cost data and the calculated time schedule. The fourth module is the optimization module which performs the cash-flow optimization process according to the set objective function. Finally, the output module which presents the optimized time schedule and cash flow to the user.

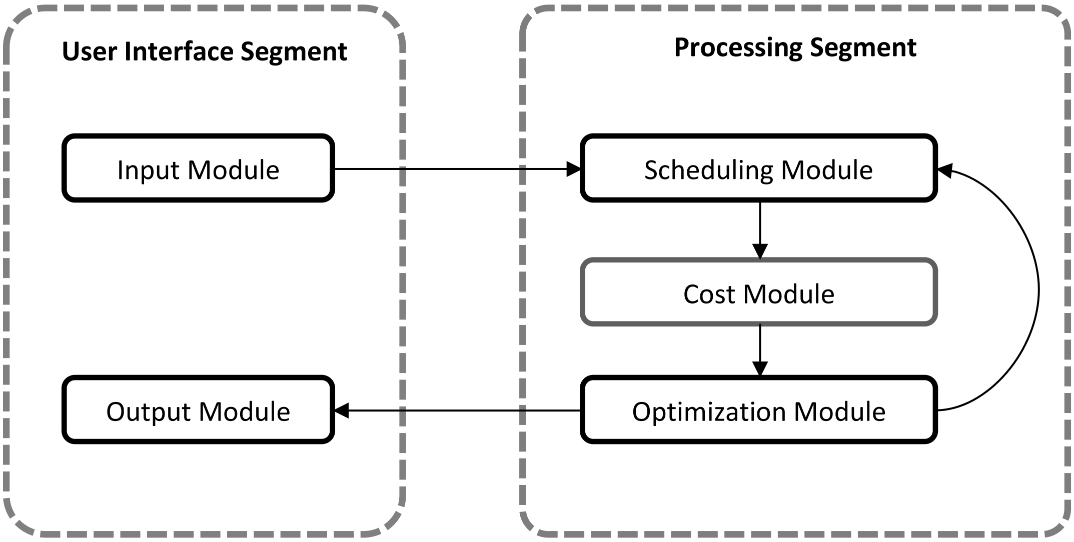

Figure 10: Developed Framework

4 . 1 . 4 DSS Development

The Decision Support System (DSS) is then developed through the integration of the above-mentioned models and other stages required for fully supporting borrowers in decision making. It is developed using Microsoft Excel and VBA to guide data input by the user and facilitate the management of data between models. It supports the user through the navigation between models and provides a final near optimum decision.

The DSS starts by a main welcome screen that introduces the user to the main stages of P4R. It starts by the borrower preparation stage which is the main focus of the DSS. At this stage the user is directed to a screen that includes all required stages of assessments, simulation and optimization. After finishing these stages and finalizing the program submission, the user returns to the DSS for applying updates from each of the identification, preparation and appraisal stages. The DSS facilitates the update/change of data resulting from these stages. It also provides a tool for monitoring and control during the implementation stage. Finally, it supports the borrowing entity in setting the total amounts received and the amounts that need to be returned to the WB.

4 . 1 . 5 DSS Verification

A case study was developed based on previous experiences in program-for-results funded programs, but in a simplified form. This case study was applied on the model and its outputs were analyzed. The model was capable of optimizing the program outputs within all possible solutions.

4 . 1 . 6 DSS Validation

Finally, the model is validated through its application on the Sustainable Rural Sanitation Services Program (SRSSP), supported by the WB through Program-For-Results mechanism in Egypt. Results from program optimization were compared to original program outputs and the optimization showed considerable improvement in the overall financial standing of the government in the program.

4 . 2 Model development

For implementing this framework, a model was developed using Microsoft Excel as a spreadsheet modeling tool, Visual Basic Applications (VBA) was applied as a modeling tool for guiding users throughout the model and Evolver Add-in to Excel was used for applying optimization using the Genetic Algorithms method. The focus of the developed model is on the borrower preparation stage as all other stages are considered updates to inputs of this stage. This model follows guidelines from the World Bank for applying the P4R mechanism; however, it can be applied to other RBF mechanisms.

The model is divided into several sheets that form the full process of RBF. It starts by a “Welcome” sheet that introduces the user to the model and its main contents, shown in Figure 11. The user views a general flow chart of the RBF (similar to Figure 4), each stage of this flow chart represents a button that directs the user to relevant steps in that stage. It also offers the user to view the full flow chart of RBF from borrower preparation to funds return.

Before proceeding with this model, the borrowing entity should have a clear understanding of the program, its scope, contents, time and cost details of each project and its activities and the relationship between them. Once a list of such items is obtained, the user proceeds to the borrower preparation sheet of the model, by pressing the “Borrower Preparation” button in the “Welcome” sheet.

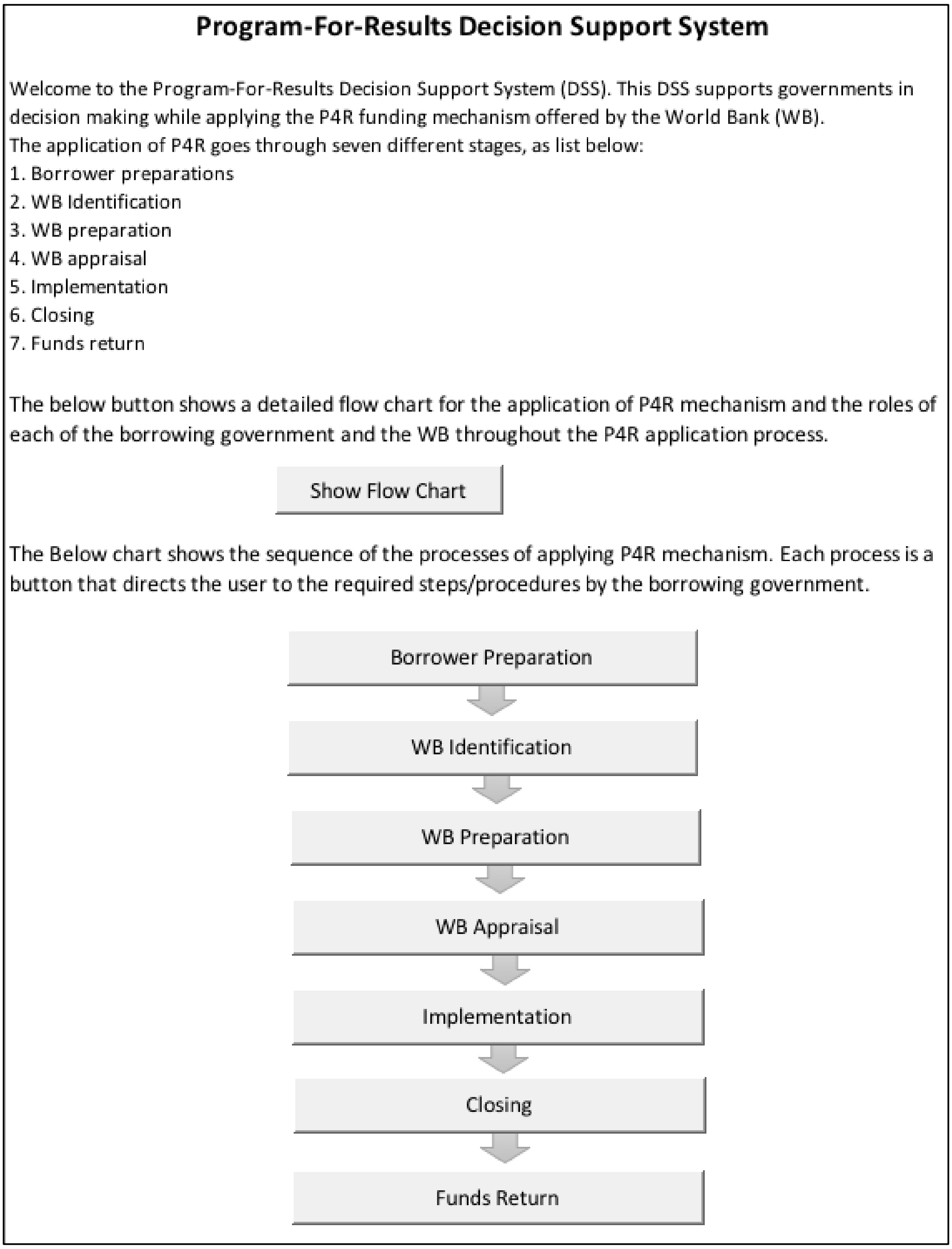

Figure 11: Welcome Sheet

4 . 2 . 1 Borrower preparation stage

The “Borrower preparation” section of the model guides the user through the required steps for preparing the P4R proposal submitted to the WB. Figure 12 shows the main screen of this section, it includes a brief of the borrower preparation stage contents and a flow chart of the processes involved. Each stage of these processes represents a button that directs the user to its relevant sheet. As shown in Figure 12, the first stage is the “General Checks”, where the user is directed to a sheet that confirms that the program, in its current state, is adequate for the P4R funding according to its limitations and rules. In the “General Checks” sheet, the user is asked three main questions, (1) If the Program Consistent with World Bank Country Assistance Strategy (CAS) / Country Partnership Strategy (CPS), and asked to confirm the answer through a “Yes” or “No” dropdown list, (2) requested to select the main implementation challenge of the program from the following three answers, whether they are the (a) policy actions, (b) project inputs and technology or (c) institutional targets with program performance, (3) if the program includes any of the following: (a) any turnkey, supply and installation contact of a value higher than USD 50 Mn, (b) purchased goods of a value higher than USD 30 Mn, (c) IT systems & non-consulting services of a value higher than USD 35 Mn or (d) any consulting services of a value higher than USD 15 Mn. Based on the answers provided, the model either confirms that the program is eligible for P4R funding as it is, redirects the government for another mechanism, or even suggest changing or excluding activities from the program to become eligible. The user has to answer all of the three questions to be able to proceed to later stages. After finishing this stage, the user presses a button to return to the borrower preparation stage, shown in Figure 12.

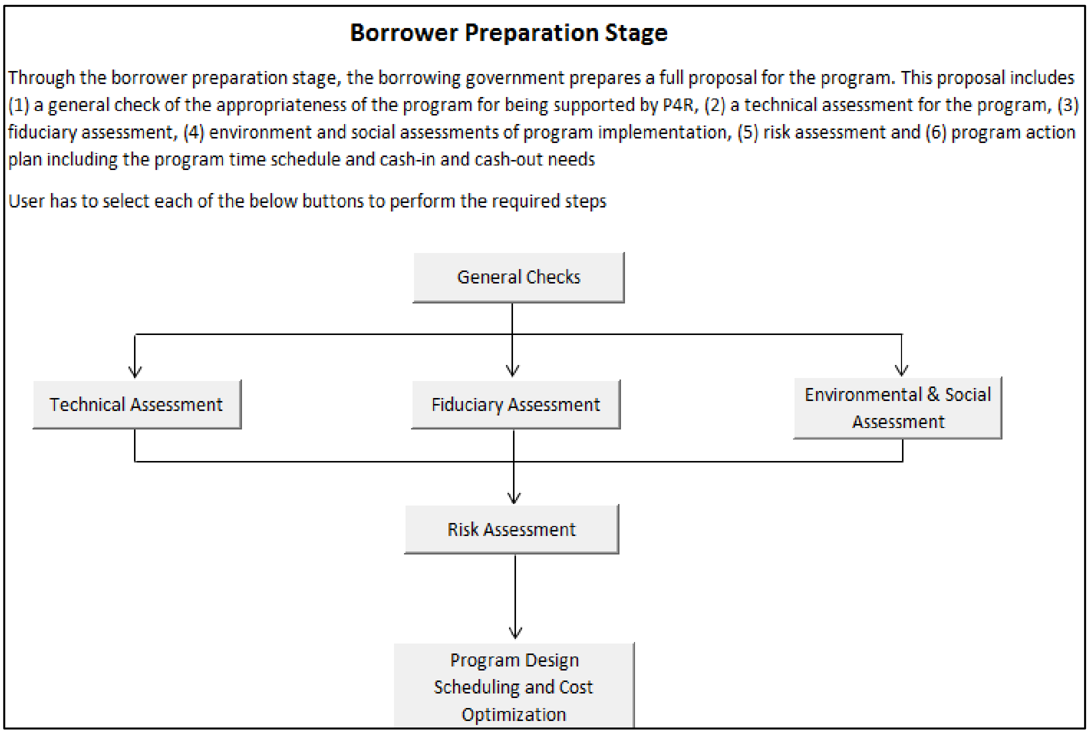

Figure 12: Borrower Preparation stage

4 . 2 . 1 . 1 Assessments

The user then proceeds to the three main assessments, (1) technical assessment, (2) fiduciary assessment and (3) environmental and social assessment. Due to the case-by-case nature of these assessments, the model only provides guidance for the user on the main contents of each assessment. The contents of each assessment are presented to the user as a checklist, where whenever the user finishes a content its checkbox is checked. Once all checkboxes are checked, the user is allowed to proceed to the next assessment. These three assessments support the government in analyzing the program in detail. After finishing all three assessments, the user can proceed to the risk assessment. The results of these assessments may affect the program inputs, that is why they have to performed as early as possible.

4 . 2 . 1 . 1 . 1 Risk Assessment Model

The risk assessment module follows the WB procedures for risk assessment, as an example for a RBF mechanism risk assessment, called Systematic Operations Risk Rating Tool (SORT); however, it focuses on the point of view of the borrowing government. This risk assessment tool uses inputs from the previous three assessments and then feeds into the program processes through updating program parameters. It is also used for supporting the WB in preparing its assessments for the program. The risk assessment process is divided into two main stages, first a survey of the main risks on P4R programs is distributed among experts in the government, for assessing the probability and impact of each risk affecting the program. The model offers the user a printable version of the risk assessment survey to be sent to experts, presented earlier in Table 4. All risks have to be rated according to their effect on the program, and not their effect generally on the market or the country. Survey respondents can also suggest other risks and include their ratings. Users are offered five different ratings to select from, (1) Low, (2) Moderate, (3) Substantial, (4) High and (5) Not Applicable. The list of risks included in these surveys is prepared based on a review of all risks included under each category defined by the WB and a survey of risks affecting previous P4R operations. These categories include (1) Political and governance, (2) Macroeconomic, (3) Sector strategies and policies, (4) Technical, (5) Institutional capacity, (6) Fiduciary, (7) Social and Environmental, (8) Stakeholders and (9) DLIs risks.

After distributing the surveys and getting enough responses from an acceptable range of stakeholders, the user returns to the model to input ratings received in each survey. The user inputs the number of times each rating was selected in-front of each risk. The model then uses these ratings to get an average impact and average probability rating for each risk. The severity of each risk is calculated by multiplying both average probability and average impact. Then risks are sorted according to their severities and presented to the user.

4 . 2 . 1 . 2 Cost and Time scheduling Optimization

After finalizing all assessments, the government will have a better understanding of the program scope, required strengthening and any required changes to the program. At this stage, the user is guided through several VBA forms/screens for the definition of program parameters. The user proceeds to the "Program Design, Scheduling and Cost Optimization" stage by pressing its relevant button, shown in Figure 12. This opens a set of screens that guide the user for entering the required data for the program.

4 . 2 . 1 . 2 . 1 Input Module

The first screen includes the input of data about the WB financial parameters for the program, as shown in Figure 13, these include: (1) Interest rate: This is the interest rate applied by the bank on the borrowed amounts, (2) Interest rate duration and compounding periods: these are the nominal interest rate duration and the compounding period duration. These two periods have to be similar to each other and to the loan re-payment intervals, (3) Loan payment duration in years and payment interval per year: this is the number of years the loan is going to be repaid in and the interval of payments within each year, (4) Commitment Fee %: This is the fee percentage calculated on the total undisbursed balance, at each of the intervals specified by the bank, (5) Commitment fee calculation frequency: this is the duration interval at which the bank calculates the remaining balance and the commitment fee as a percentage of it. For example, if this interval is six months, then every six months the bank deducts disbursed amounts from the total loan amount to multiply this amount by the fee percentage and (6) Front End fee: this is the percentage set by the bank to be deducted at the beginning of the program. This fee can be paid by the borrowing country or deducted from the loan amount. In this model, it is assumed to be deducted from the loan amount. After finishing all inputs, the user presses “OK” to be directed to the second screen.

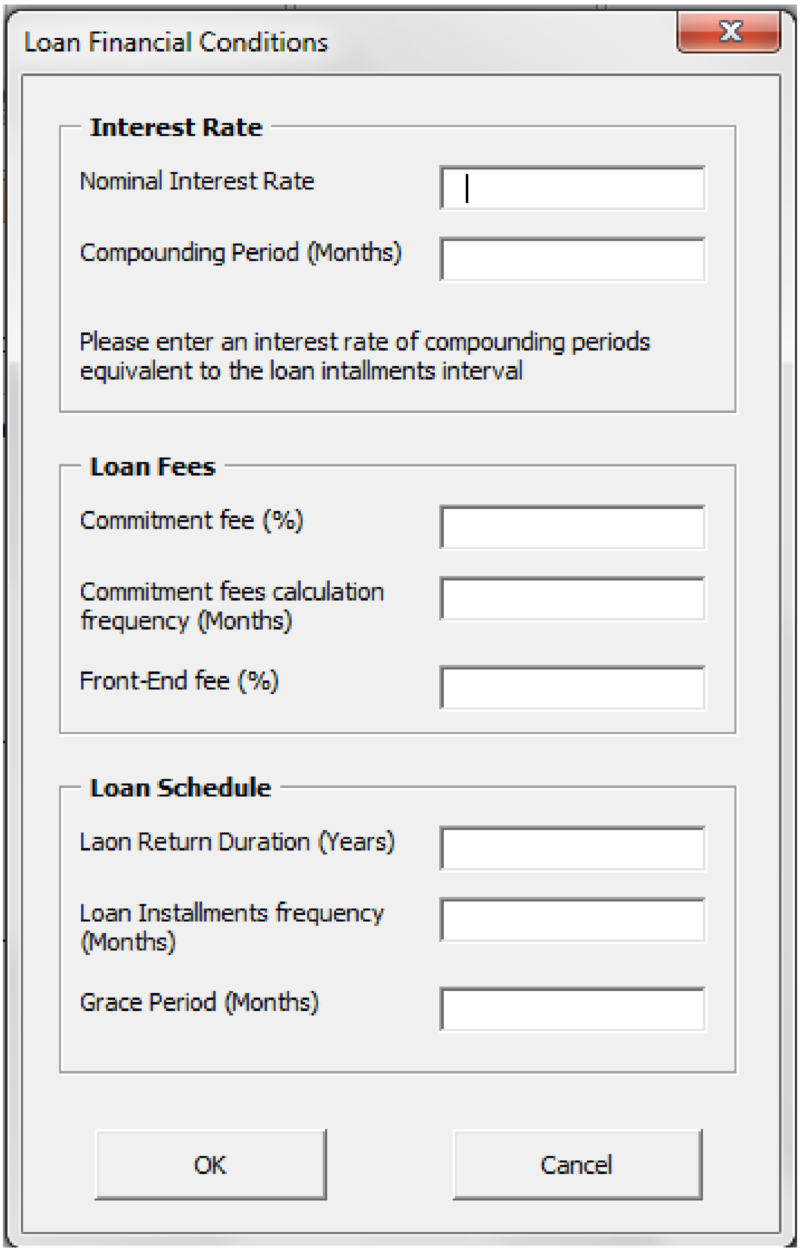

Figure 13: Loan Financial Conditions Screen

The second window includes the input of general data about the program, as shown in Figure 14, such as: (1) Start Date: the calendar date of the planned start date of program. This date has to be the start date of any required strengthening activities required prior to starting in the program and the date for receiving advance payment, (2) Inflation rate: this is the annual inflation rate added on costs of activities. This inflation rate is added on costs of activities/projects according to their start dates, based on the assumption that activities already include construction inflation (inflation from the start of their relevant project to the start in activity), (3) Advance payment %: this is the percentage of advance payment from the total amount of the loan. This percentage is later deducted from payments allocated for each DLI amount, (3) DLIs approval duration: this is an assumed duration between the achievement of any DLI and the receival of its relevant disbursement amount. This duration is set for the activities that should be done by the borrowing government for verifying the DLI achievement, applying for the required payment, getting the bank's approval and adding amounts to the government's account and (4) Government to Implementing agencies transfers frequency: this defines the periods at which governments makes financial transfers for implementing agencies. After finishing all inputs, the user presses "OK" to be directed to the third screen.

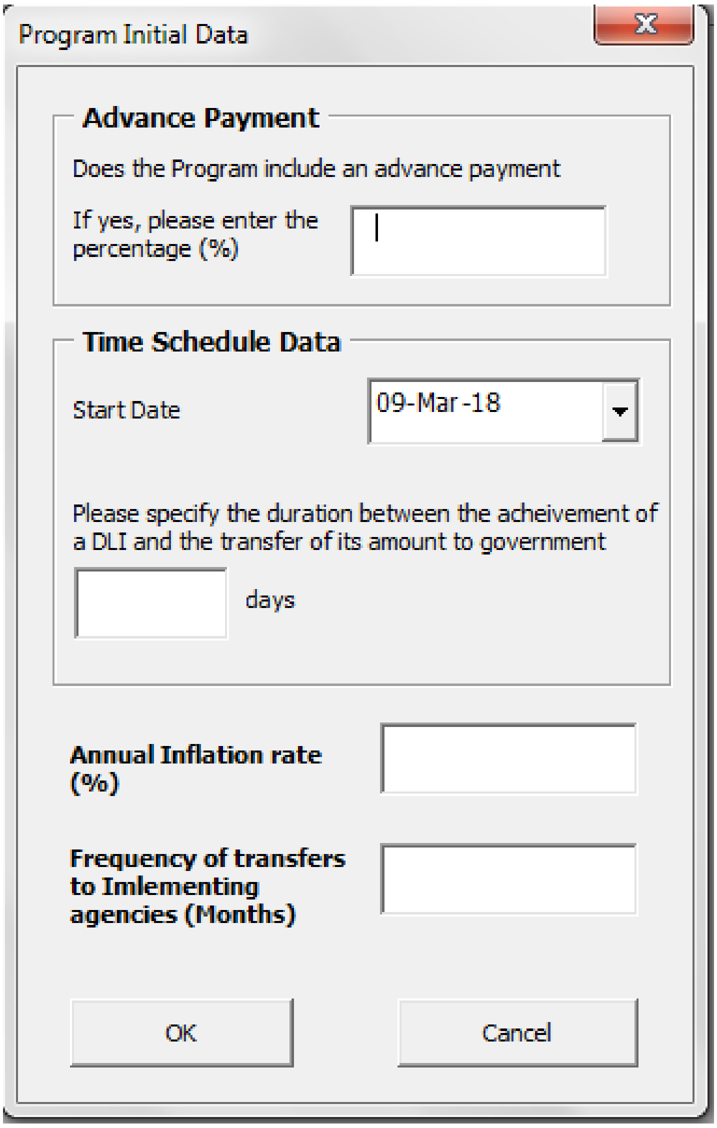

Figure 14: Initial Data screen

The user then uses the screen in Figure 15 to define the program parties holding responsibilities for each of the program projects. The user adds a code for each entity and its description, then presses “Next” to define the next one. After defining all entities, the user presses “define Result Areas” to proceed to the next step.

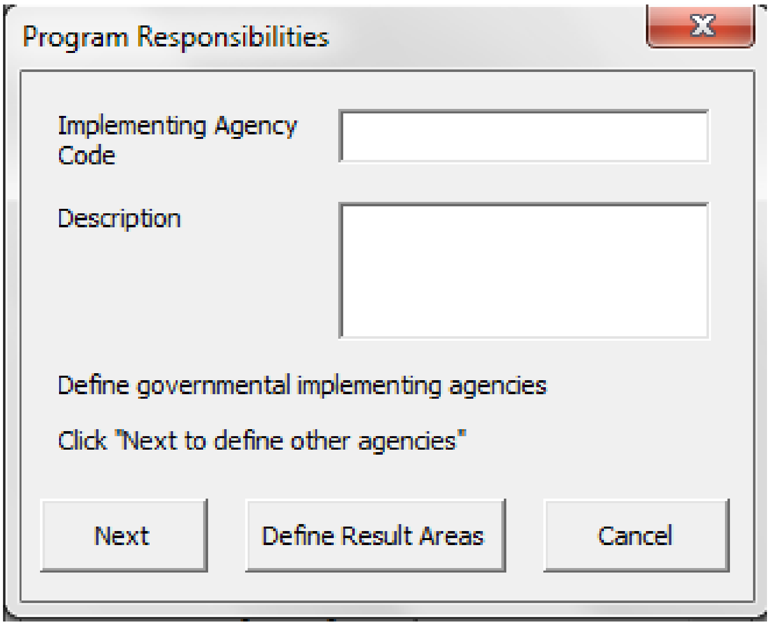

Figure 15: Program Responsibilities definition

After entering the required data, the screen in Figure 17 opens and requests the user to define the result areas of the program. Starting from this phase, the user is guided through several screens to define each result area, its breakdown of DLIs, projects defining each DLI deliverables and activities falling under each project (Zahran & Ezeldin, 2017-A), as shown in Figure 16. This classification follows the definition of the WB for the contents of previous operations.

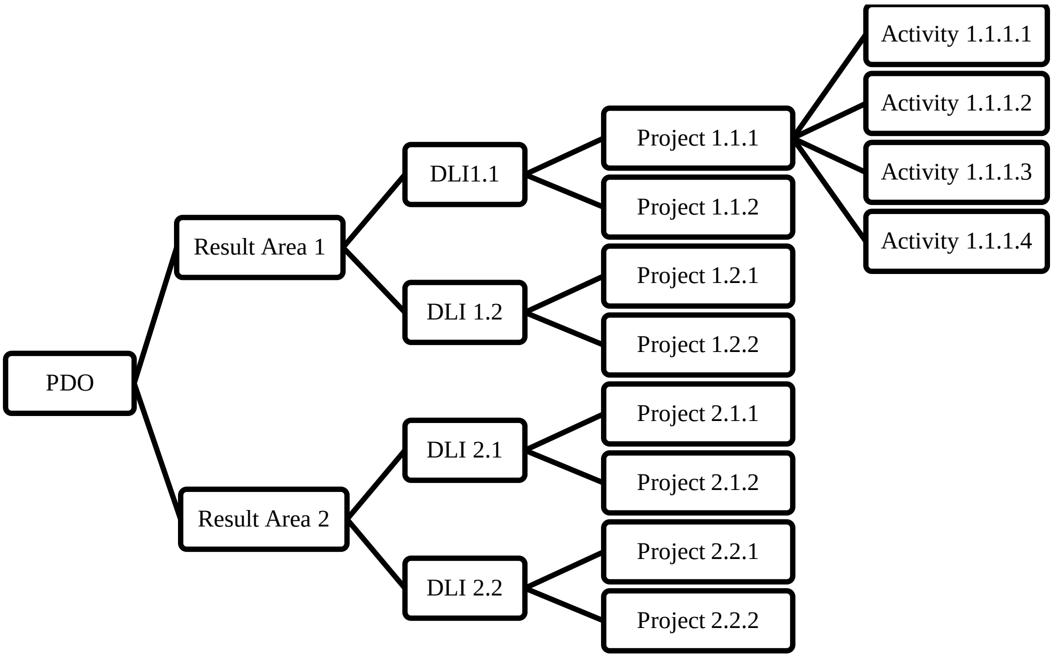

Figure 16: Classification of program contents (Zahran & Ezeldin, 2017-A)

The ID of each result area is automatically added by VBA, as this numbering is then translated into a code in the model. After inserting all result areas, by pressing "OK" after each result area description inserted, the user presses the "Define DLIs" button to move to the next screen for defining DLIs.

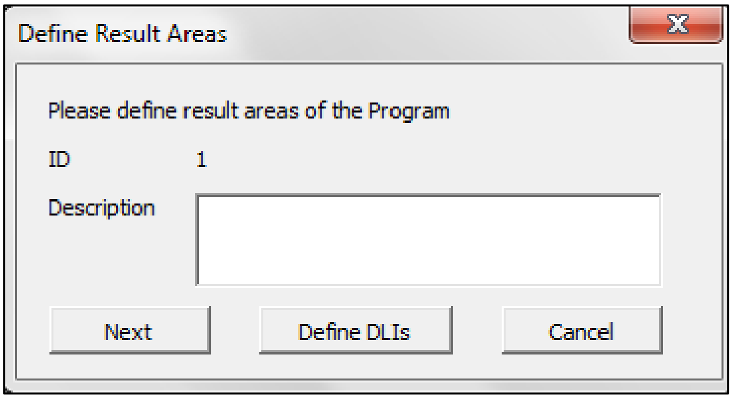

Figure 17: Define Result Areas Screen

The user then starts in defining DLIs under each result area, this is done by selecting the result area previously inserted from a dropdown menu and entering the description relevant to it, as shown in Figure 18. Each DLI defined is also coded after the number of its result area and its order under the result area, for example, the first DLI under the first result area is coded “1.1”.

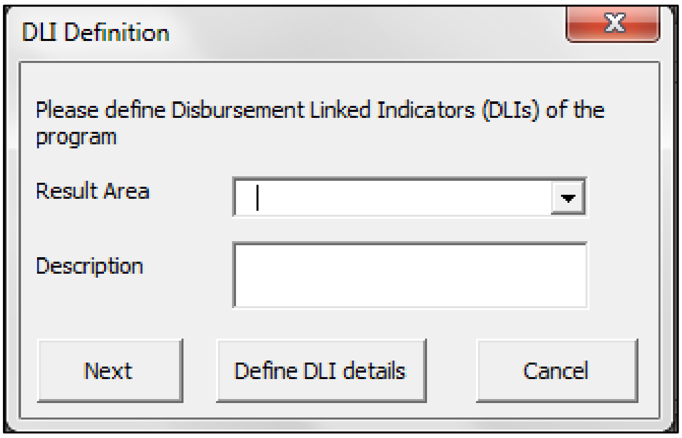

Figure 18: DLIs definition screen

After inserting all DLIs under each result area, the user proceeds for the definition of the details of each DLI, as shown in Figure 19. At this stage, the user has the freedom of defining different alternatives for DLIs, to be discussed with the WB. The user starts by selecting the DLI, from the dropdown menu of DLIs just defined. For each DLI selected the user defines the following: (1) the Alternative number, alternative #1, #2, ...etc., (2) total amount allocated for the DLI, (3) the distribution of the amounts over the DLI, if it is scaled over the DLI progress or it is related to a threshold, (4) start amount or advance payment, the amount paid to the government once it starts in the DLI implementation, (5) Repetitive payment and (6) repetition duration, these represent any expenses relevant to the DLI that repeat on a regular basis, for example monthly salaries of stakeholders working on the DLI, (7) End payment, the amount paid to the government when finishing all works relevant to the DLI and (8) disbursement activities, the user enters the descriptions of activities falling under the

DLI once finished the government receives disbursements for them and also enters the amounts relevant to each activity achievement.

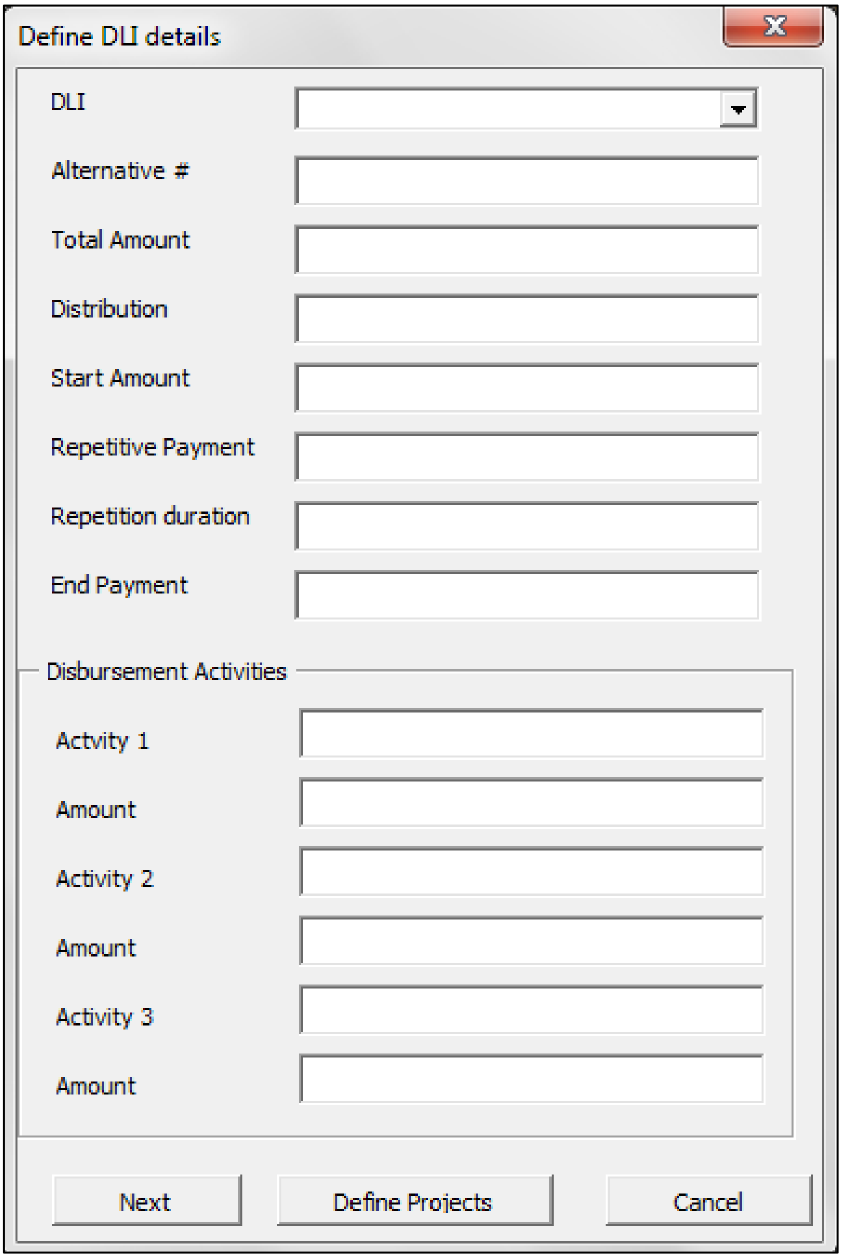

Figure 19: DLI details definition

After entering all details of DLIs and any suggested alternatives for each DLI, the user presses the "Define Projects" button, Figure 20 screen requests the user to insert general details about each project falling under each DLI. The user (1) selects the DLI of the entered project, (2) enters the project description, (3) enters the advance payment percentage, if any, (4) retention amount, if any, (5) the relevant retention duration and (6) select the program stakeholder responsible for the financial management of this project. For each project, a code is generated representing its result area, DLI and its order under the DLI, so the first project under the first DLI under the first result area is coded "1.1.1". After inserting data for all projects, the user presses the "Next" button to enter data of the next project, until all projects are added.

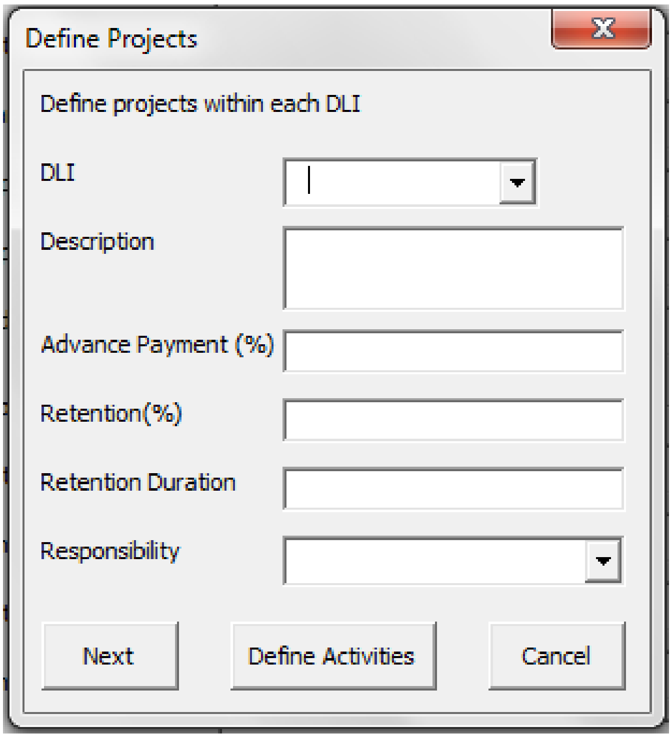

Figure 20: Projects Definition

The user then presses the "Define Activities" button to start in the definition of activities under each project. Figure 21 shows the screen used for defining activities. For each activity the user (1) selects its project from a dropdown menu of recently defined projects, (2) enters its description, (3) durations minimum duration it can be compressed to, average duration it takes under normal working conditions and the maximum duration it can be extended to, (4) define the set of predecessors for the activity from dropdown menus having other activities previously inserted, (5) cost data of activities including the total cost of activity, (6) advance payment amount of the activity, (7) any required uniform payments over the lifetime of activity, if any, (8) end payment, if any required payments at the end of the activity, (9) retention amount and duration it is retained. The user keeps defining activities by pressing the “Next” button after entering data of each activity. Each activity is coded after its order under its project, DLI and result area.

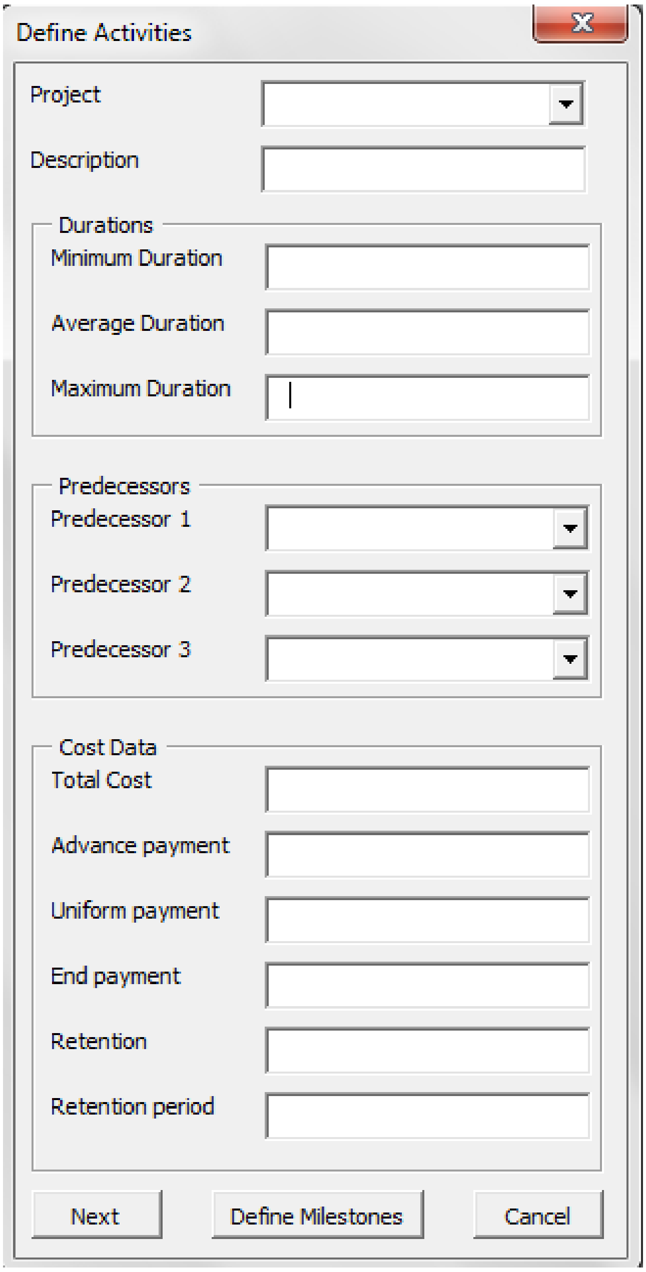

Figure 21: Activities Definition

After defining all activities required under all projects, the user presses the "Define Milestones" button to continue to define project milestones, if any. Figure 22 shows the screen used for defining milestones. For each milestone, the user (1) enters its description, (2) required date, (3) selects from a dropdown list its relevant item either it is an activity, project or a DLI and (4) its relation to such item, either it is the start or finish, from a dropdown list. After inserting all milestones data, the user presses the "View Inputs" button to view all inputs added. After viewing all inputs and confirming them, the user presses a confirmation button for confirming all data is correct and the model can proceed with running the model.

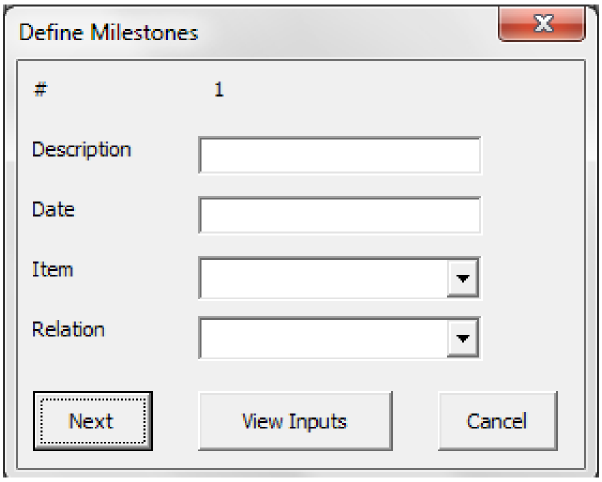

Figure 22: Milestones definition

4 . 2 . 1 . 2 . 2 Scheduling Module

The scheduling module is responsible for handling time related inputs for producing a detailed time schedule for the program. This module is considered the main driver for other modules within the processing segment. It is responsible for determining the flexibility within the program time schedule for absorbing any changes that result in an optimized cash flow. This flexibility is utilized later in the optimization module.

Based on the activities durations and interdependencies, for each activity, its early start (ES), early finish (EF), late start (LS), late finish (LF), total float (TF) and free float (FF) are calculated. The calculation of these parameters is shown in equations listed below. The main difference in these equations that they do not only consider successors or predecessors within the same project, but they also consider other relationships within the full program.

ES =Maximum ($EF_{\text{predecessor activities}}$), or zero if no predecessors [1]

EF = ES + Duration [2]

LF = Minimum (LS successor activities) or total program duration if no successors [3]

LS = LF – Duration [4]

TF = LS – ES or LF – EF [5]

$FF_{Act} = LS_{successor} - LF_{Act}$ [6]

A final time schedule is then calculated using early dates of each activity plus a lag duration that is defined later in the optimization module. This lag is initially set to zero. Equation 7 shows the calculation method of the start date of this schedule. It is represented by the early start of the activity plus a lag duration, that is initially set to be zero, this start date has to be less than the late start initially calculated for that activity. Based on this start date, the finish date is the start date plus the activity duration, that is also a variable in the optimization process.

$$\text{Start} = ES + Lag \leq LS \qquad [7]$$

The scheduling process of this type of programs is performed upwards, where activities are scheduled first, then based on the activities within each project its dates are determined. Projects within each DLI determine its dates and DLIs within each result area define its dates. This module was adjusted from Fayad et al (2012) to allow for considering multiple projects and different project types.

4 . 2 . 1 . 2 . 3 Cost Module

This module is responsible for calculating the detailed cash flow of the program. It uses general program data, WB financial parameters, projects/activities data for calculating the cash-in and cash-out schedules of the program. The only source for cash-in considered in this model is the support received from the WB. This support can be defined in different methods where it can be linked to (1) the start date of program (advance payment), (2) start date of DLI, (3) end date of DLI achievement, (4) a repetitive payment (such as monthly salaries) or (5) achievement of milestones/activities within target projects. The definition of cash-out in this case depends on defined responsibilities. Responsibility for the finance of projects/DLIs is divided into two categories, (1) government directly supported activities/tasks and (2) governmental implementing agencies supported activities. In this case, governments commonly make annual or semi-annual transfers to implementing/coordinating ministries for ensuring sufficient cash flow is available whenever required. The amounts of these transfers are based on the agencies plans for such periods. This means that the government has two sorts of spending, (1) the first is for government supported activities which is paid when required and (2) annual or semi-annual transfers to implementing/coordinating ministries.

The cost module consists of three interrelated subsections, (1) Cost Scheduling, (2) responsibilities cash flows and (3) Amortization schedule calculation.

4.2.1.2.3.1 Cost Scheduling

After setting all dates for cash out requirements, the inflation percentage defined earlier is applied on all costs based on their duration from the program start date. As shown in equation 8, inflation rate is added on project costs as they are moved forward in time, where the cost of a project at time t is equal to the cost of that project at the start date of the program multiplied by one plus i, that is the interest rate per period, to the power of n, that is the number of interest period between the start date and the date required for calculating inflation.

$$\text{Cost}_{\text{at date t}} = \text{Cost}_{\text{at project start}} * (1 + i)^{n} \qquad [8]$$

Scheduling and cash flow calculations follow methods used by Fayad et al (2012); however, this model uses different concepts in calculating cash flows, as it considers responsibilities for each activity/project. This lies in the allocation of each of the considered amounts in the cash flow to its responsible stakeholder. The main output from this subsection is a cost loaded time schedule that is linked to all inputs from scheduling and input modules.

4.2.1.2.3.2 Responsibilities Cash Flows

This translates into one main cash flow for the financial management responsible ministry, that is responsible for coordinating financing with the WB, and other cash flows for each one of the implementing agencies. The main cash flow of the financial management ministry/government considers costs of main activities covered by it, annual or semi-annual transfers for implementation and support received from the WB. This cash flow is considered the main reference for program financial management. Based on the cumulative cash-in and cash-out of this cash flow, the government’s spending on this program is calculated. Spending on program is the difference between cash-in and cash-out at any point of time (t), as shown in equation 9.

$$\text{Government spending}_t = \text{Cash-In}_t - \text{Cash-Out}_t \quad [9]$$

This model is concerned with the maximum amount of spending and its date, so it is calculated by the model and reported later to the user. The model also calculates the monthly cash-flow/spending requirements, for being included in the government's plan in financing the program's deficit, this is calculated by deducting the cumulative cash-in from the cumulative cash-out. Cash flows of implementing agencies allow for planning activities managed by implementing ministries/agencies for agreed periods of time. This ensures no spending from the implementing ministries on the program. So, the overall difference between cash-in and cash-out, of these stakeholders, is always higher than or equal to zero. This is later used to ensure an optimum plan for implementing ministries that considers overall cash flow and ministry's internal cash flow.

4 . 2 . 1 . 2 . 3 . 3 Amortization Schedule

After calculating cash flow requirements on a daily basis for each of the program parties, a detailed expenditure schedule is calculated for the government. After setting all cash flow requirements, schedule of DLI achievement and calculating dates for WB disbursement, the installments for returning the borrowed amounts is calculated. In this case the interest rate is calculated between the date of disbursement and the date of returning amounts. A typical cash flow of this type of programs starts by the borrowing government getting disbursements for the total duration of the program and then returns borrowed amounts through installments either after the program ends directly or after a grace period. The installments amount is calculated by considering the amortization schedule planned for the program and the future value of disbursements at the beginning of the fund returning duration. This produces an amortization schedule that reflects any changes made to the program schedule. Figure 23 demonstrates the cash flow diagram of a typical P4R program. The amounts received during the program duration should be equivalent to the amounts returned during the installments return period, while considering time value of money. So, the future value of the amounts disbursed to the borrowing government, at the end of the program duration or the end of the grace period should be equivalent to the present value of all installments at the same date, as shown in equation 10. The main output from this subsection is the amount paid in each installment, according to the set frequency and duration set for repayment.

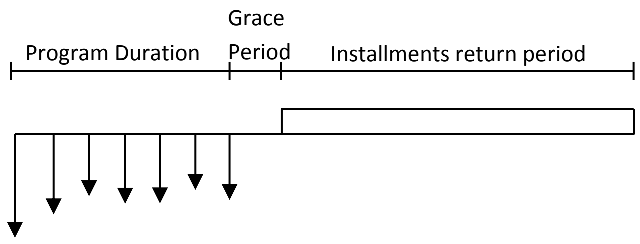

Figure 23: Amortization Schedule

$$\text{Installments} = FV_{\text{(amounts received in account of program)}} * (1+i)^{G} * \frac{i*(1+i)^{n}}{(1+i)^{n}-1} \qquad [10]$$

i: the interest rate per period

G: the number of interest periods on the grace period

N: the number of interest periods in the installments return period

The two main outputs from this module that are going to be used in the optimization module are the (1) maximum amount of spending required by the government on the program for ensuring undisturbed flow of the program schedule and

(2) the amount of each installment returned to the bank. These two outputs shape the main targets of the government for delivering a successful program.

4 . 2 . 1 . 2 . 4 Optimization Module

Figure 24 shows the steps of the optimization process where it starts from the inputs stage where the user already added all required data, then the scheduling module for calculating a detailed time schedule. Then the cost module which loads the time schedule calculated with cost data and calculates the finance gap and installments amounts. Then the optimization module which keeps changing alternatives entered by the user and recalculates schedule and cost modules, until it reaches a near optimum solution, that is later presented to the user in the output module.

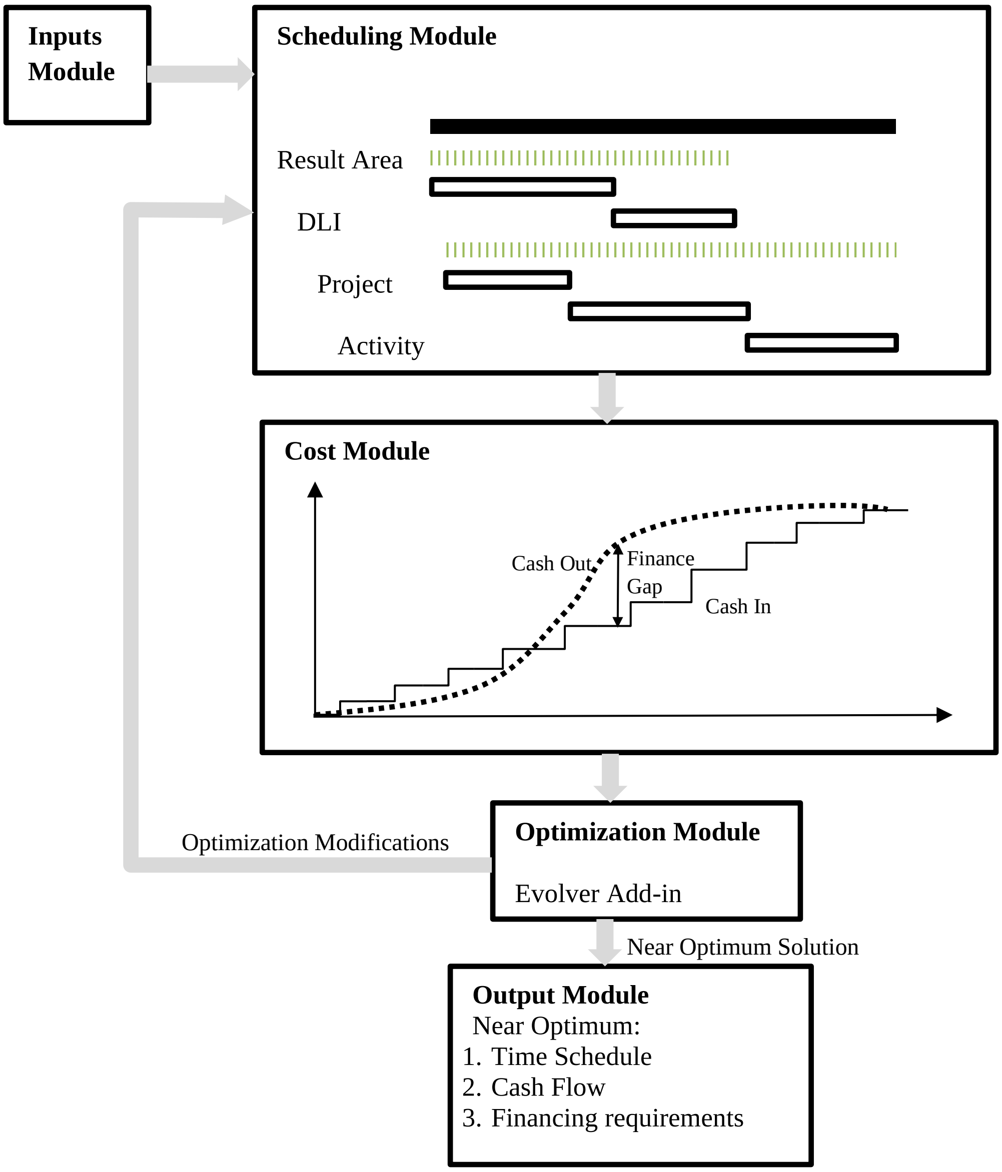

Figure 24: Scheduling and Cost Optimization Flow Chart

This module is designed to consider three variables for deciding upon a near-optimum time schedule from a financial point of view. These comprise (1) activity start dates, where activities on non-critical paths (having a float more than zero), can change their start dates for a duration up to their float duration. This variable is represented by a lag value between its early start date and its actual start date. The optimization process works on changing this lag value between zero and the maximum float amount for each specific activity, as shown in equation 11.

$$S_i = ES_i + X_i \leq LS_i \qquad [11]$$

Where LS_i is the late start of activity i that is considered the maximum allowable value for that activity to start, (2) Activity durations, durations of scalable activities that have different possible durations (minimum duration up to the maximum duration) can be changed during the optimization process. The optimization process works on selecting the best possible duration for each activity, between its minimum and maximum possible durations, as shown in equation 12.

$$D_{i\ min} \leq D_i \leq D_{i\ max} \qquad [12]$$

Where $D_{i\ min}$ and $D_{i\ max}$ are the minimum and maximum allowed durations for activity i to be crashed or extended, (3) DLI alternatives, the selection among different options for each DLI. The optimization process works on selecting the most suitable DLIs distribution among available options. This variable can only be used before the WB starts in setting preferred DLIs. Several constraints are also considered, including (1) maximum available spending by the government on the program, if any, (2) the maximum allowed duration for this program and (3) the achievement of program milestones and activities/projects relationships, as shown in equation 13.

$$DLI_{i.1} \leq DLI_i \leq DLI_{i\ n} \qquad [13]$$

Where the spectrum of selecting among DLI alternatives available ranges from $DLI_{i.1}$ as the first DLI alternative listed to the last alternative called $DLI_{i.n}$. This framework offers the government the flexibility to select among different options for optimization. It can be set to minimize the overall duration of the program while considering a maximum spending constraint or minimize the overall spending of government on the program while considering the amounts of loan returning installments. In this case the objective function is set to minimize the multiplication of both the loan installment and the maximum expenditure of the government on the program throughout its lifetime. This aims to maintain the balance between spending the adequate amount of money on the program while managing to return an optimum amount of money to the WB through installments.

This optimization process is performed on Microsoft Excel as a spreadsheet modeling tool and genetic algorithm optimization is run using Evolver Add-in. Figure 25 shows the optimization settings Evolver Add-in, used for applying Genetic Algorithms (GA) optimization. Model settings screen is divided into three parts, (1) the first part represents the optimization goal (objective function), as shown in equation 14, which is to decrease (a) the maximum amount for the financing gap, which represents the maximum spending of the government on the program, (b) the amount of installment paid for returning the borrowed loan and (c) the average monthly spending of the government on the program.

$$\text{Objective Function} = \text{Minimize}\ (FG * L * MAS) \qquad [14]$$

FG: maximum finance gap

L: Loan installment amount

MAS: monthly average spending of government on program

This section can be edited later for adapting any goal the user needs to fulfil. (2) The second section represents the optimization variables which are (a) the durations of activities to vary between the minimum duration and the maximum duration, (b) the lag duration each of the non-critical activities, that are not on the critical path, can be delayed and (c) the choice between alternatives of DLIs defined by the user. (3) The third section of the optimization settings are the constraints of the model which are (a) the lag constraint which ensures that all lags applied do not affect the overall duration of the program and are within the float of the activity and (b) the milestones constraint which ensures that all milestones are achieved in their required time.

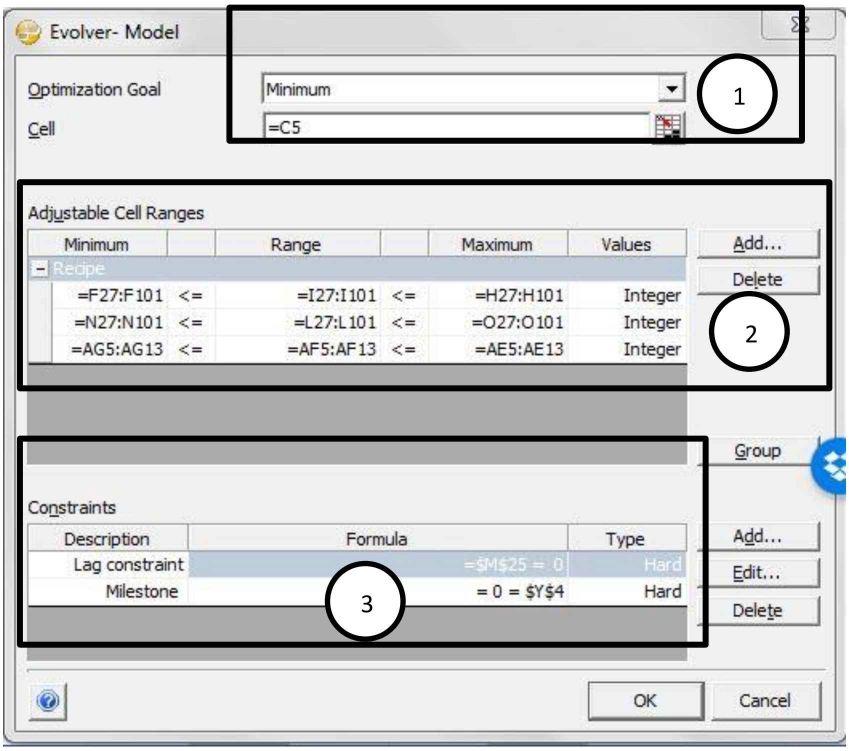

Figure 25: Evolver Add-in Optimization settings

Fitness evaluation is determined through the selected objective function, for example a better (fit) population, in case selecting the objective function of decreasing the overall spending on program and decreasing the returned loan amount, is the population that has a lower value for the multiplication of the loan value, maximum spending and average monthly spending. Once a near optimum result is reached, optimization outputs are presented in the output module.

4 . 2 . 1 . 2 . 5 Output Module

The output module is designed to provide the optimization outputs in different forms, for facilitating their application. It offers outputs in excel tables format, graphical representation and offers the option to export the time schedule to Microsoft Project. In the Output module, the following is presented to the user (1) the main selections of the model of DLIs, set by the optimization process, (2) a confirmation that all milestones were achieved, or a list of any milestones that were not achieved and need to be reconsidered or removed and (3) a detailed time schedule for each of the contents of the program (R.A., DLIs, projects and activities) including their start date and finish date before and after applying optimization to assess the effect of optimization and the need for making the changes. This time schedule can be extracted to Microsoft Project for better visualization or the time schedule. The resulting near optimum time schedule has to consider the program milestones, else this will be shown to the user, to either drop these milestones, negotiate changing them or change program inputs to consider them. The detailed schedule is divided according to the responsibilities of each of the program parties. The government uses these schedules for managing other program stakeholders and their financial requirements, and it is also sent to these stakeholders for managing their projects. It also enables the government plan backwards any steps required for getting disbursements, such as the online application form required by the World Bank in case of the Program-For-Results mechanism. (4) A detailed cash flow diagram representing daily cash-in and cash-out requirements, and another monthly cash-in and cash-out diagram. This is also graphically presented in a cash flow diagram format for visualizing financial transfers throughout the program lifecycle. This provides the government with a detailed schedule for its required spending on the program. These outputs enable the government identify cash flow requirements from the WB and others required from the general budget. (5) A detailed monthly schedule of expenditures presented in an excel table format. This schedule sets the outline for government spending on the program and supports future plans of the general budget. This schedule also alerts the government of its required capabilities during the program lifecycle. If any of the required spending schemes does not comply with the government capabilities or plans for such period, it could be added to the program constraints to be considered while performing optimization.

4 . 2 . 2 Identification stage

In the identification stage, the government will have to reflect any feedback from the WB on the model. At this stage, the user is redirected to the “Welcome” page for pressing the “WB Identification” button. To be directed to the screen shown in Figure 26, where the user selects which items to be added or edited. After adding/editing inputs the model is re-run to provide the government with a new near optimum solution.

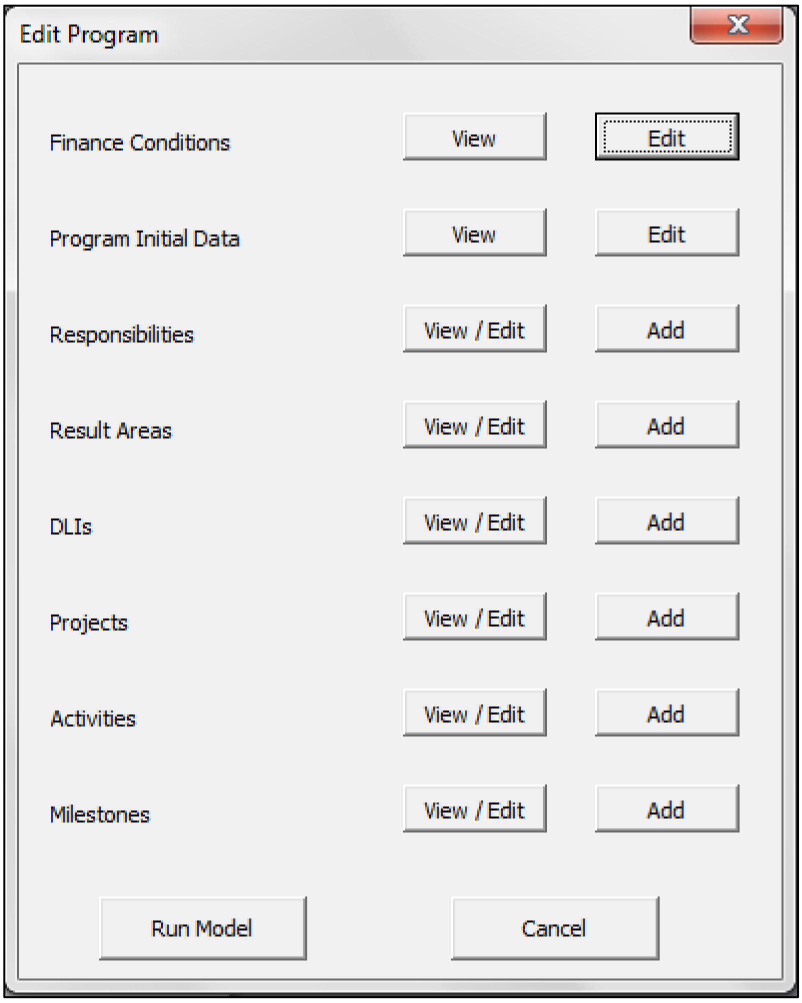

Figure 26: Edit Program Screen

4 . 2 . 3 Preparation

In the preparation stage, most of the tasks performed are done by the WB task team, so the government will only use the assessments performed to support the WB in performing these assessments. At the end of the preparation stage, the government will have to include any updates based on the WB assessments in the model through similar steps mentioned in the identification stage. At this stage the user is also directed to the screen shown in Figure 26.

4 . 2 . 4 Appraisal Stage

In the appraisal stage, the government performs continuous negotiations with the WB on the program using the model outputs, which will enable the government have a continuously updated near optimum target for aiming to reach from negotiating the WB. At each stage of negotiation, the government has to get back to the model and apply any updates or suggestions from the WB to assess its effect on the program. At this stage, most of the flexibility offered to the government in selecting milestones or DLIs may not be available; however, it may add further restrictions to the program.

4 . 2 . 5 Implementation stage

Through the implementation stage, the government uses the model for monitoring and control of the implementing agencies and continuously updating program parameters according to the actual progress of the program. This translates mainly into the update of assessments, especially the risk assessment, and the update of activities costs and durations. The update of actual durations of activities and the application of productivity rates on future estimates of durations and costs, may lead to the need for re-running the model and obtaining new implementation targets from optimization. This run of the model may have the highest number of constraints as it has to respect all agreements made with the WB and can only allow activities that were not specifically settled with the WB.

This optimization process is different from other previous processes as it only considers variables for activities that did not start yet. This means that the optimization module will only offer activities that did not start the option to change their durations or start dates, while DLIs are left as is as they are already agreed with the WB.

4 . 2 . 6 Closing

In the closing stage, the model helps the government have an overall summary for the program total amount for summarizing the amounts that need to be returned to the WB. This amount is calculated similar to the method described in the amortization schedule within the cost module; however, it reflects actual amounts borrowed and not planned amounts, such as the case in the borrower preparation stage.

4 . 2 . 7 Summary

This chapter introduced the methodology of the proposed framework and a summary of its procedures. It started through the review of literature performed, which led to the definition of the problem behind this research. Then it introduced the proposed framework for solving such problem. The general layout of the developed model's framework was introduced. It presented the optimization and risk management modules and how they get their desired outputs. Then it presented how these were integrated into a decision support model that facilitates the application of such models on P4R supported programs. Then, this decision support system was applied on a P4R supported program for validating its capability of providing acceptable results. It then summarized the steps for building the decision support model for applying Program-For-Results funding mechanism on mega infrastructure programs, as one of the RBF mechanisms offered by international financial institutions. This model simulates the seven processes described by the WB, for applying P4R. It focuses on the Borrower Preparation stage, as it has the highest flexibility in planning for the target program, which translates in a higher number of tasks to be performed. Other stages of P4R application represent an update for inputs used in the model and all other processes are automatically repeated. This chapter described the main building blocks of the model and how they are used throughout the program lifecycle. It described the main inputs required for using the model and its expected outputs and capabilities. The model described in this chapter used processes and tasks required by the WB for applying P4R; however, these steps can be applied on other RBF mechanisms.

CHAPTER 5: VERIFICATION

To verify the performance and structure of the developed model, a simplified program was designed by the author. This case study was built based on previous operations; however, several parameters were assumed to illustrate the capabilities of the model. This case study resembles a typical program that has a main Program-Development-Objective, that is broken down into several result areas. The financial relationship between the borrower and lender is defined by specific Disbursement-linked-Indicators, which are specified goals that should be reached to get agreed disbursements. Each DLI is broken down into projects, represented by a set of different activities. This chapter explains the application of the model on the case study, presents the model features and provides an explanation of the model outputs.

5 . 1 Inputs / Assumptions

The model inputs are divided into four categories, (1) the main classification of the R.A.s, DLIs, Projects and activities, (2) Lending Bank conditions and financial data , (3) list of milestones and (4) list of DLI alternatives. Table 5 shows the list of items added in the model (Result areas, DLIs, Projects and activities). It describes the scheduling data for each activity, such as its minimum, average and maximum duration and its list of predecessors. The average duration is the duration that the activity is executed in under normal working conditions, the maximum duration is the longest duration the activity can be extended to when decreasing the productivity and the minimum duration is the least duration the activity can be achieved in after applying crashing. This program includes two result areas, each result area is broken down into several DLIs and under each DLI several projects that include a number of activities.

For example, the first result area (RA 1) includes two DLIs, the first DLI (DLI 1.1) has two different projects (Project 1.1.1 & Project 1.1.2) while the second (DLI 1.2) has only one project (Project 1.2.1). The first project (Project 1.1.1) has six activities (activity 1.1.1.1 to activity 1.1.1.6).

Responsibilities within this program are divided among three stakeholders. Institution A is the main governmental institution that is responsible for the overall financial management of the program and coordinating between other institutions. Institutions B and C are responsible for the management of projects within the program and follow the main plan designed by institution A. These two institutions have to ensure having no spending on the program. This is achieved by making financial transfers for each one of them that covers their plan for that period, by institution A. Responsibilities within the program are divided among these three institutions.

Scheduling data is only added for activities as it is considered the driver for other scheduling information of projects, DLIs and result areas. Relationships are only set to be between activities, this means that if an activity has to start after a specific project ends, its predecessor is set to be the last activity of that project (or its finish milestone).

Table 5: case study scheduling inputs

		Duration			Predecessors		
Code	Description	Min. Dur.	Avg. Dur.	Max Dur.	Pred. 1	Pred. 2	Pred. 3
1	Result Area 1						
1.1	DLI 1.1						
1.1.1	Project 1.1.1						
1.1.1.1	Activity 1.1.1.1	50	75	100			
1.1.1.2	Activity 1.1.1.2	25	50	75	1.1.1.1		
1.1.1.3	Activity 1.1.1.3	50	75	100		1.1.1.1	
1.1.1.4	Activity 1.1.1.4	75	100	125	1.1.1.3	1.1.1.2	

		Duration			Predecessors		
Code	Description	Min. Dur.	Avg. Dur.	Max Dur.	Pred. 1	Pred. 2	Pred. 3
1.1.1.5	Activity 1.1.1.5	150	175	200	1.1.1.4		
1.1.1.6	Activity 1.1.1.6	50	60	75	1.1.1.5		
1.1.2	Project 1.1.2						
1.1.2.1	Activity 1.1.2.1	50	75	100	1.1.1.6		
1.1.2.2	Activity 1.1.2.2	50	100	125	1.1.2.1		
1.1.2.3	Activity 1.1.2.3	60	75	100	1.1.2.1		
1.1.2.4	Activity 1.1.2.4	150	175	200	1.1.2.2		
1.1.2.5	Activity 1.1.2.5	150	175	200	1.1.2.3		
1.1.2.6	Activity 1.1.2.6	75	90	100	1.1.2.5	1.1.2.4	
1.2	DLI 1.2						
1.2.1	Project 1.2.1						
1.2.1.1	Activity 1.2.1.1	75	100	125		1.1.1.6	
1.2.1.2	Activity 1.2.1.2	100	125	150	1.2.1.1		
1.2.1.3	Activity 1.2.1.3	75	100	125	1.2.1.2		
1.2.1.4	Activity 1.2.1.4	100	125	150	1.2.1.3		
1.2.1.5	Activity 1.2.1.5	75	100	125	1.2.1.4		
2	Result Area 2						
2.1	DLI 2.1						
2.1.1	Project 2.1.1						
2.1.1.1	Activity 2.1.1.1	50	75	100		1.2.1.5	
2.1.1.2	Activity 2.1.1.2	150	175	200	2.1.1.1		
2.1.1.3	Activity 2.1.1.3	50	75	100		2.1.1.1	
2.1.1.4	Activity 2.1.1.4	75	100	125	2.1.1.2		
2.1.1.5	Activity 2.1.1.5	200	225	250	2.1.1.3		
2.1.1.6	Activity 2.1.1.6	50	60	75	2.1.1.5	2.1.1.4	
2.1.2	Project 2.1.2						
2.1.2.1	Activity 2.1.2.1	50	75	100		2.1.1.6	
2.1.2.2	Activity 2.1.2.2	100	125	150	2.1.2.1		
2.1.2.3	Activity 2.1.2.3	50	75	100	2.1.2.2		
2.1.2.4	Activity 2.1.2.4	75	100	125	2.1.2.3		
2.1.2.5	Activity 2.1.2.5	100	125	150	2.1.2.4		
2.1.2.6	Activity 2.1.2.6	50	60	75	2.1.2.5		
2.2	DLI 2.2						
2.2.1	Project 2.2.1						
2.2.1.1	Activity 2.2.1.1	75	100	125	1.1.2.6		
2.2.1.2	Activity 2.2.1.2	100	125	150	2.2.1.1		
2.2.1.3	Activity 2.2.1.3	75	100	125	2.2.1.1		
2.2.1.4	Activity 2.2.1.4	100	125	150	2.2.1.2		
2.2.1.5	Activity 2.2.1.5	75	100	125	2.2.1.4	2.2.1.3	

The cost data and responsibilities of each element added in the model is shown in Table 6. In case of cash-out, total costs are added for each activity. The total cost of a project is the sum of costs of all activities included in it. For each project the user inserts a percentage for advance payment to be calculated of the total project cost and paid at the project start date, a percentage for an end payment to be paid at the finish date of the project, a percentage for retention/delayed payment and a retention duration. The advance payment percentage, end payment percentage and the retention percentages are deducted from activities within the project to get the amount for invoicing of progress during the lifecycle of the project for each activity.

Table 6: Case study cost data

		Cost Data (Cash Out)						Cash-In	Transfer		
Code	**Description**	**Total cost**	**Advance payment**	**Uniform payment**	**End payment**	**Delayed payment**	**Delay Period**	**DLI Amount**	**Responsible**	**Recipient**	**Payee**
1	Result Area 1										
1.1	DLI 1.1										
1.1.1	Project 1.1.1		20%			5%	365		B		
1.1.1.1	Activity 1.1.1.1	10,000,000		7,500,000							
1.1.1.2	Activity 1.1.1.2	10,000,000		7,500,000							
1.1.1.3	Activity 1.1.1.3	10,000,000		7,500,000							
1.1.1.4	Activity 1.1.1.4	10,000,000		7,500,000							
1.1.1.5	Activity 1.1.1.5	10,000,000		7,500,000							
1.1.1.6	Activity 1.1.1.6	10,000,000		7,500,000							
1.1.2	Project 1.1.2		20%			5%	365		C		
1.1.2.1	Activity 1.1.2.1	10,000,000		7,500,000							
1.1.2.2	Activity 1.1.2.2	10,000,000		7,500,000							
1.1.2.3	Activity 1.1.2.3	10,000,000		7,500,000							
1.1.2.4	Activity 1.1.2.4	10,000,000		7,500,000							
1.1.2.5	Activity 1.1.2.5	10,000,000		7,500,000							
1.1.2.6	Activity 1.1.2.6	10,000,000		7,500,000							
1.2	DLI 1.2										
1.2.1	Project 1.2.1		20%			5%	365		A		
1.2.1.1	Activity 1.2.1.1	10,000,000		7,500,000							
1.2.1.2	Activity 1.2.1.2	10,000,000		7,500,000							
1.2.1.3	Activity 1.2.1.3	10,000,000		7,500,000							

		Cost Data (Cash Out)						Cash-In	Transfer		
Code	**Description**	**Total cost**	**Advance payment**	**Uniform payment**	**End payment**	**Delayed payment**	**Delay Period**	**DLI Amount**	**Responsible**	**Recipient**	**Payee**
1.2.1.4	Activity 1.2.1.4	10,000,000		7,500,000							
1.2.1.5	Activity 1.2.1.5	10,000,000		7,500,000							
2	Result Area 2										
2.1	DLI 2.1										
2.1.1	Project 2.1.1								A		
2.1.1.1	Activity 2.1.1.1	10,000,000	5,000,000		5,000,000						
2.1.1.2	Activity 2.1.1.2	10,000,000	5,000,000		5,000,000						
2.1.1.3	Activity 2.1.1.3	10,000,000	5,000,000		5,000,000						
2.1.1.4	Activity 2.1.1.4	10,000,000	5,000,000		5,000,000						
2.1.1.5	Activity 2.1.1.5	10,000,000	5,000,000		5,000,000						
2.1.1.6	Activity 2.1.1.6	10,000,000	5,000,000		5,000,000						
2.1.2	Project 2.1.2		15%			5%	365		A		
2.1.2.1	Activity 2.1.2.1	10,000,000		8,000,000							
2.1.2.2	Activity 2.1.2.2	10,000,000		8,000,000							
2.1.2.3	Activity 2.1.2.3	10,000,000		8,000,000							
2.1.2.4	Activity 2.1.2.4	10,000,000		8,000,000							
2.1.2.5	Activity 2.1.2.5	10,000,000		8,000,000							
2.1.2.6	Activity 2.1.2.6	10,000,000		8,000,000							
2.2	DLI 2.2										
2.2.1	Project 2.2.1		15%			5%	365		A		
2.2.1.1	Activity 2.2.1.1	20,000,000		16,000,000							
2.2.1.2	Activity 2.2.1.2	20,000,000		16,000,000							

		Cost Data (Cash Out)						Cash-In	Transfer		
Code	**Description**	**Total cost**	**Advance payment**	**Uniform payment**	**End payment**	**Delayed payment**	**Delay Period**	**DLI Amount**	**Responsible**	**Recipient**	**Payee**
2.2.1.3	Activity 2.2.1.3	15,000,000		12,000,000							
2.2.1.4	Activity 2.2.1.4	15,000,000		12,000,000							
2.2.1.5	Activity 2.2.1.5	15,000,000		12,000,000							

For example, in project 1.1.1 an advance payment of 20% is paid at the beginning of the project and a retention of 5% is retained for one year. The stakeholder responsible for this project is institution “B”. In case of project 2.1.1, activities within this project are of a different nature where payments for these activities are made at the beginning and the end of the activity only. This model allows for the inclusion of any types of activities within the program, not only activities of construction projects.

Financial conditions of the loan are presented in Table 7. The interest rate assumed for this program is 2% semi-annual interest rate compounded semi-annually. For obtaining this loan the government has to pay two fees, 0.25% for the commitment fee that is calculated semi-annually on the undisbursed balance and 0.25% as a front-end fee that is deducted from the loan amount in the beginning of the program. This loan is returned over 30 years while considering no grace period. Laon payments are made each 6 months.

Table 7: Loan Financial Conditions

Interest Rate	
Nominal Interest rate	2%
Compounding period (Months)	6 months
Loan Fees	
Commitment fee	0.25%
Commitment fee calculation frequency	6 months
Front-end fee	0.25%
Amortization Schedule	
Loan Return Duration	30 years
Loan Installments frequency	6 months
Grace Period	0

Initial data of the program is presented in Table 8. An advance payment of 25% is assumed for this program, this amount is paid at the beginning of the program from the lending institution to the borrowing government. The start date of the program is set to be the 1st of July 2018. The time between the achievement of a DLI and receiving its disbursement amount after getting the bank and verification agent's approval is assumed to be 30 days. The annual inflation rate is set to be 3%. The planning duration that is set for transfers between the government and governmental implementing agencies is set to be 6 months.

Table 8: Program Initial Data

Advance Payment	25%
Start Date	01/07/2018
DLI achievement approval duration	30 days
Annual Inflation rate	3%
Transfers frequency to implementing agencies	6 months

The assumed list of milestones is presented in Table 9. This includes the start date and finish date and two milestones for the finish dates of two projects (1.1.2 and 1.2.1).

Table 9 List of Milestones

	Description	Date	Related Item	Relation
M.1	Start Date	01/07/2018	Start	Start
M.2	Finish Date	31/03/2024	Finish	Finish
M.3	Project 1.1.2 Finish	13/10/2021	1.1.2	Finish
M.4	Project 1.2.1 Finish	13/10/2021	1.2.1	Finish

Different alternatives for each DLI are presented in Table 10. In case of DLI 1.1, the total amount allocated for it is 100Mn, this amount is disbursed as both a threshold amount at the end of the achievement of the DLI and scaled amounts relevant to smaller tasks within the DLI achievement. Once the government starts in activities required for achieving this DLI it receives an amount of 20Mn. Three different amounts are set for the finish of activities within the DLI achievement. The government receives 10Mn when achieving each one of these activities. Finally, when the DLI is achieved the government receives a total amount of 50Mn. Repetitive payments were not assumed in this program.

Table 10: List of DLIs Alternatives

#	Alt.#	Total Amount	Distribution	Start Amount	Repetitive payment	Repetition duration	Act. 1	Act.1 Am.	Act. 2	Act.2 Am.	Act. 3	Act.3 Am.	Finish Am.
1.1	1	100,000,000	T & S	20,000,000			1.1.1.3	10,000,000	1.1.1.6	10,000,000	1.1.2.3	10,000,000	50,000,000
1.1	2	100,000,000	T & S	10,000,000			1.1.1.3	8,000,000	1.1.1.6	7,000,000	1.1.2.3	10,000,000	65,000,000
1.2	1	50,000,000	T & S	5,000,000			1.2.1.2	10,000,000	1.2.1.4	10,000,000			25,000,000
1.2	2	50,000,000	T & S	8,000,000			1.2.1.2	7,500,000	1.2.1.4	7,500,000			27,000,000
2.1	1	90,000,000	T & S	10,000,000			2.1.1.3	10,000,000	2.1.1.6	10,000,000	2.1.2.3	10,000,000	50,000,000
2.1	2	90,000,000	T & S	20,000,000			2.1.1.3	9,000,000	2.1.1.6	8,000,000	2.1.2.3	8,000,000	45,000,000
2.1	3	90,000,000	T & S	30,000,000			2.1.1.3	8,000,000	2.1.1.6	6,000,000	2.1.2.3	6,000,000	40,000,000
2.2	1	59,250,000	T & S	5,000,000			2.2.1.2	9,250,000	2.2.1.4	10,000,000			35,000,000
2.2	2	59,250,000	T & S	8,000,000			2.2.1.2	4,250,000	2.2.1.4	5,000,000			42,000,000

5 . 2 Model Implementation

The above data was used in the model to test its reliability and ability to produce valid results. This section explains the processes used for the input of data in the model, model calculations and the main outputs from the model.

5 . 2 . 1 Input module

The following figures show steps followed to input data of the case study in the model. It starts by Figure 27 for the definition of loan financial conditions. Figure 28 is used for the definition of the program initial data. Figure 29 is used for the definition of the list of responsible program stakeholders, this figure is repeated until all responsible stakeholders are defined. Figure 30 is used for the definition of the result areas within the program, this figure is repeated until all result areas are defined. Figure 31 is used for the definition of program DLIs under each result area, this figure is repeated until all DLIs are inserted. Figure 32 is used for inserting the details of each of the DLIs defined before, this figure is repeated until the details of all DLIs are added. Figure 33 is used for the definition of the details of projects under each DLI, this figure is repeated until details of all projects are added. Figure 34 is used for the definition of activities within each project, this figure is repeated until all activities are added. Figure 35 is used for the definition of program milestones, this figure is repeated until all milestones are defined.

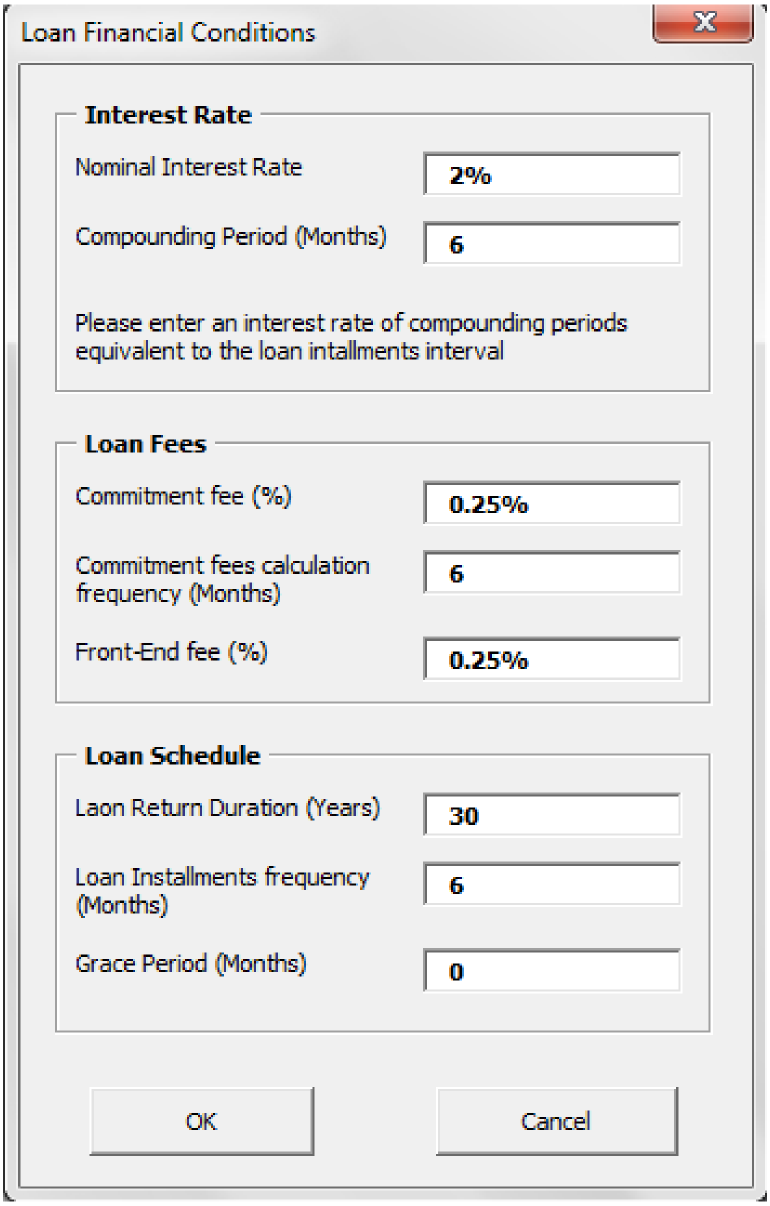

Figure 27: Loan Financial Conditions - case study

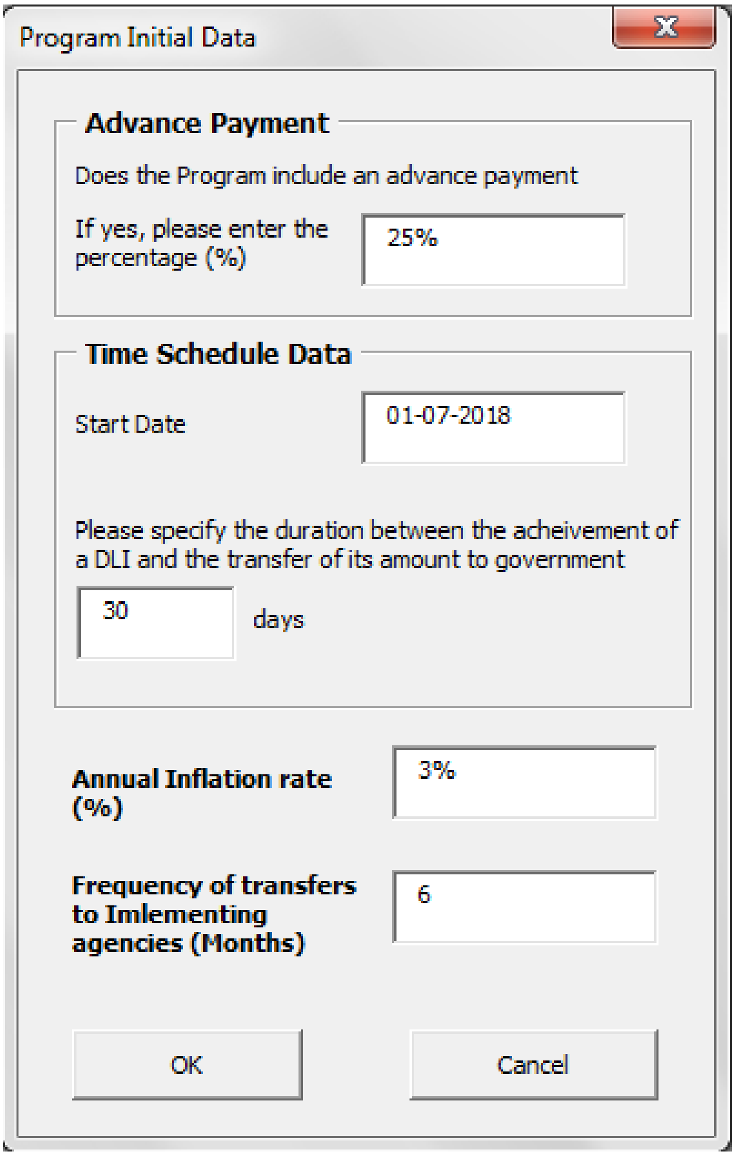

Figure 28: Program Initial Data - case study

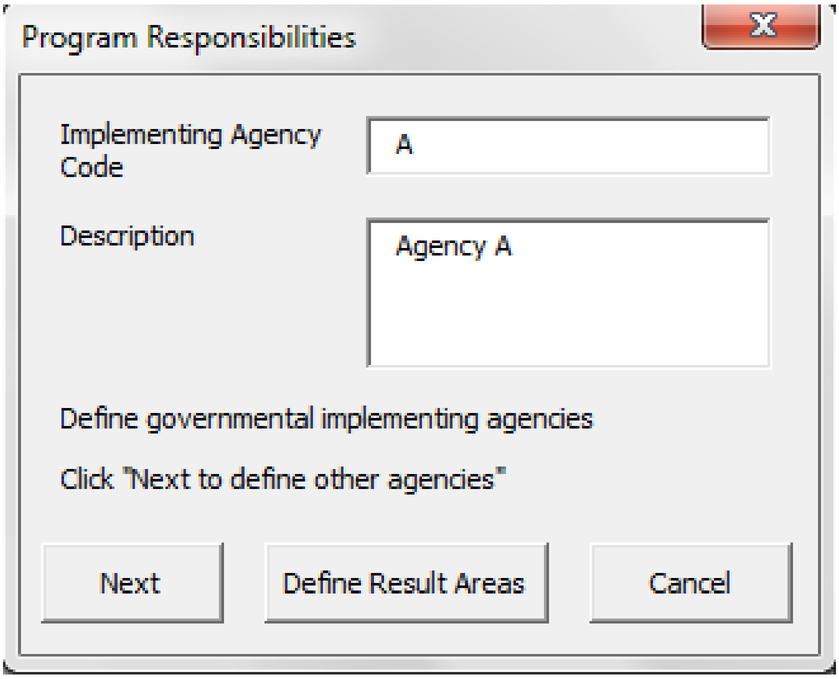

Figure 29: Program responsibilities - case study

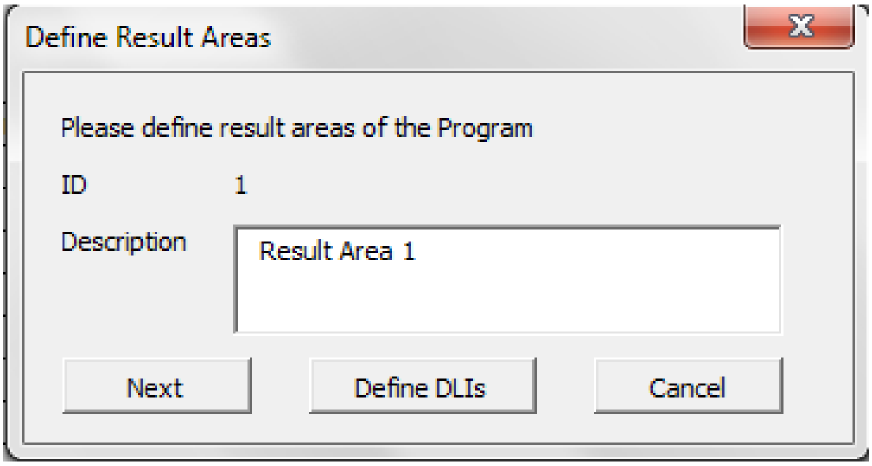

Figure 30: Result Areas definition - case study

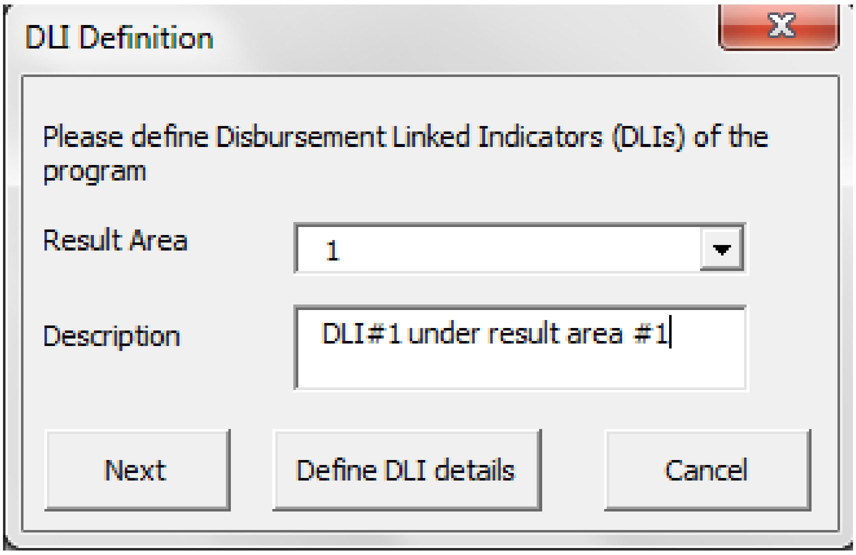

Figure 31: DLI definition - case study

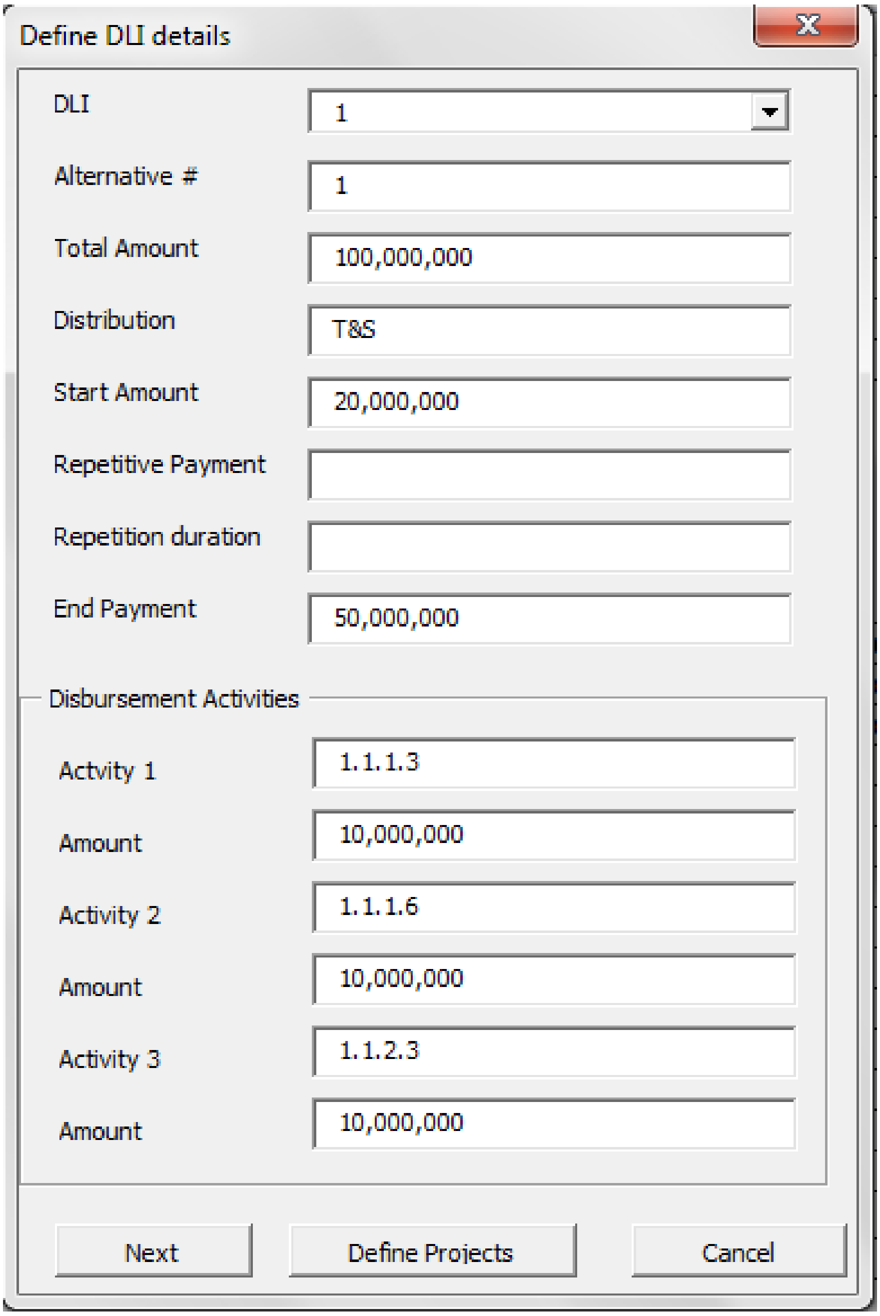

Figure 32: DLI details definition - case study

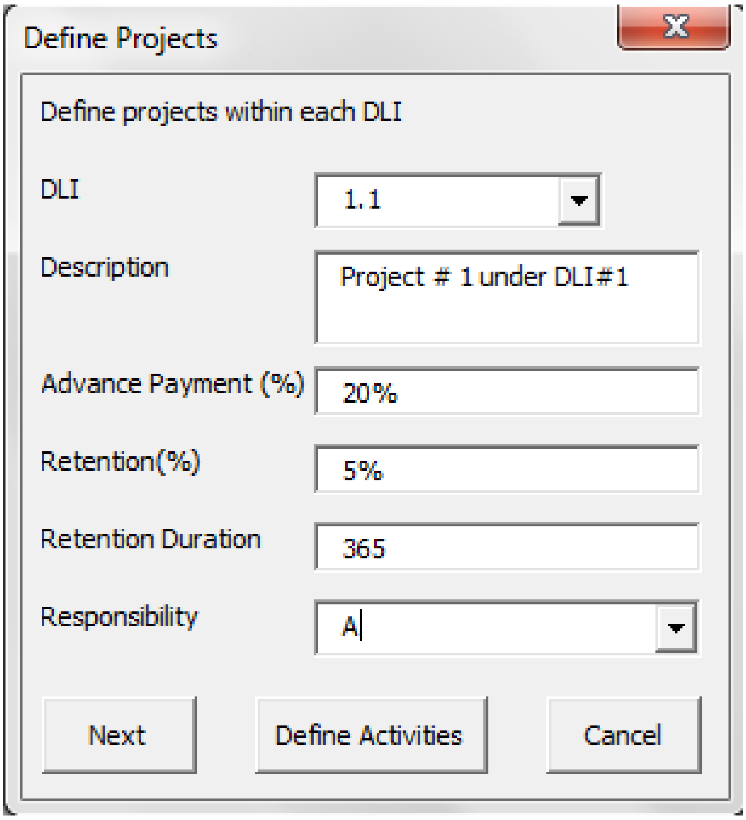

Figure 33: Projects definition - case study

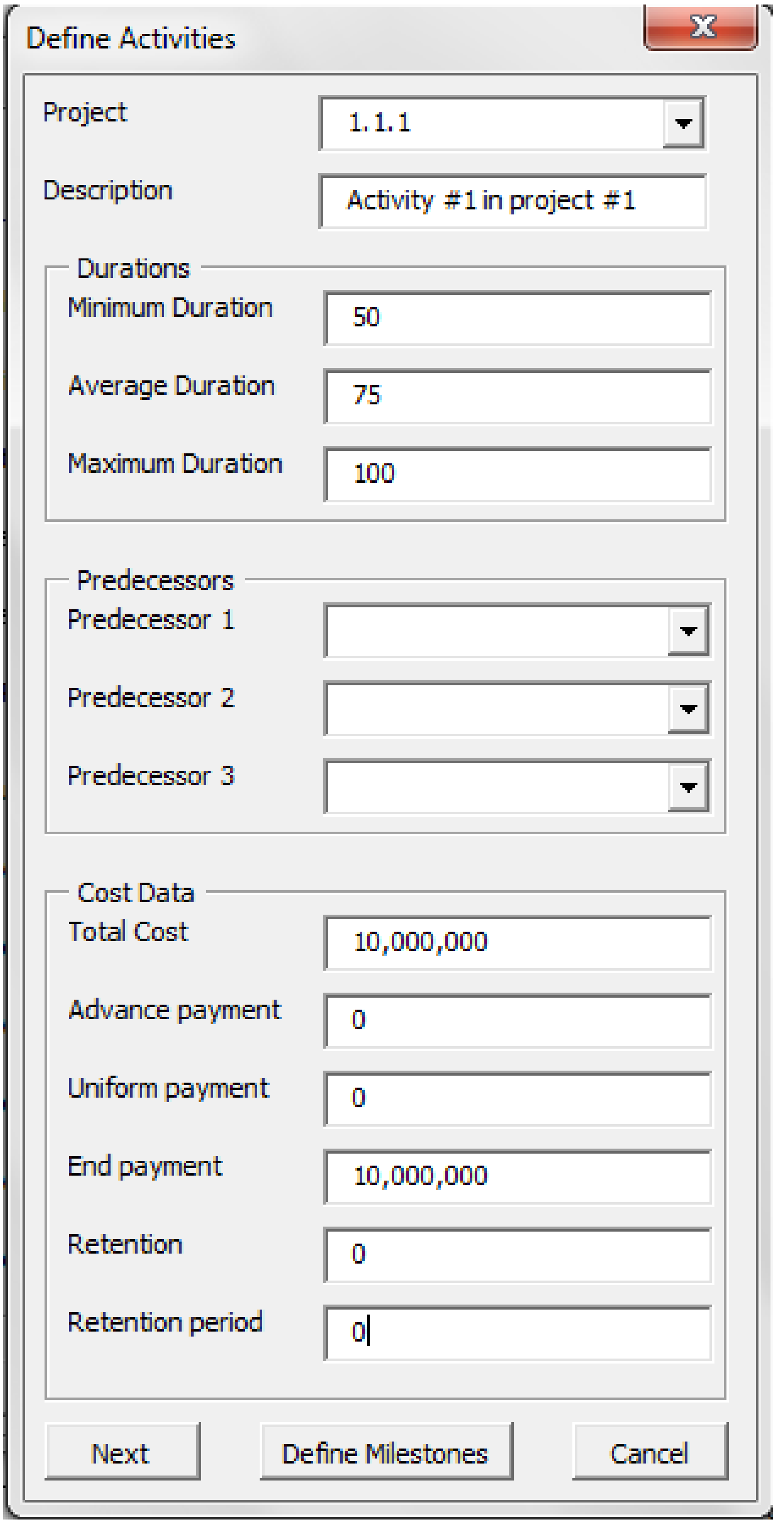

Figure 34: Activities definition - case study

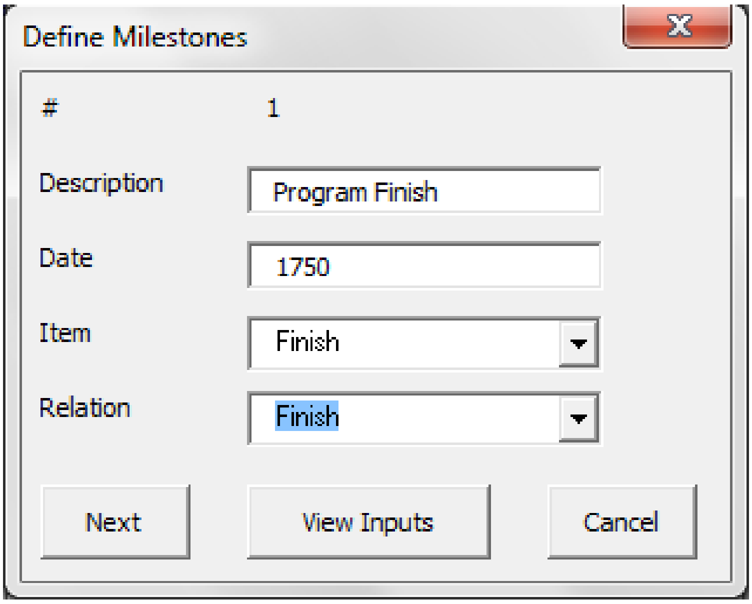

Figure 35: Milestones definition - case study

5 . 2 . 2 Scheduling Module

Scheduling data obtained from the input module is used in this module for calculating a detailed time schedule for the program. The total duration of the program, without considering any optimization performed, is 2030 days. Table 11 shows the detailed calculations of the program time schedule. This starts by setting the list of predecessors of each activity. This model allows activities to have up to three predecessors. Calculations within this table are driven by activities, this means that activity dates are calculated and based on these dates the dates of projects, DLIs and result areas are calculated. After getting the predecessors and durations of activities, this module calculates the early start, early finish, late start and late finish of each activity. Durations mentioned in this table are brought from the optimization module, based on the optimization process selection, and not from the input module. For example, activity 1.1.2.1 has the predecessor activity 1.1.1.6, so it has the early start date of day 486 and early finish of day 560 (75 days of duration after its start date), same applies for the late start and late finish calculations. Based on these dates the total float and free float are calculated. So, activity 1.1.2.1 has a total float of 655 days, which means that it can be moved for 655 days without affecting the total duration of the program. It has a zero free float so any delay in its finish date delays the succeeding activities. The lag amounts at this stage are set to be zero, as no optimization is run yet. The last two columns in the table are for the shifted/optimized schedule. This is the schedule that includes any changes resulting from the optimization process, this includes any changes due to the change of activity duration or adding lag duration to the start dates of activities.

Figure 36 shows the bar chart schedules resulting from the original time schedule calculated for the program. This time schedule is plotted on monthly units for presenting the program easier. Dark colored bars represent the originally scheduled program, while the grey bars represent the amount of float each of the scheduled items has. For example, result area #1 is scheduled to start from the beginning of the program to the middle of year 2021; however, it has available float until near the end of year 2022. This is caused by the floats of activities included in project 1.1.2 that can be extended to October 2022.

This stage of scheduling only considers the provided program scheduling information and does not consider any of the milestones/constraints defined earlier by the user. This is delayed to the optimization stage to find out the optimum method for considering these milestones. The program at this stage has a finish duration that is 70 days less than the total duration defined earlier in the milestones. This means that the program, if needed, can be extended by 70 days without affecting the required milestones.

Table 11: Scheduling Module - case study

Activity Code	Predecessors			Duration	Type	Scheduling						X (Lag)	Shifted Schedule	
	Pred. 1	Pred. 2	Pred. 3			ES	EF	LS	LF	TF	FF		Start	Finish
1					**R.A.**	**1**	**1035**	**1**	**1580**	**545**			**1**	**1035**
1.1					DLI	1	925	1	1580	655			1	925
1.1.1					Proj.	1	485	1	485	0			1	485
1.1.1.1				75	Act.	1	75	1	75	0	0	0	1	75
1.1.1.2	1.1.1.1			50	Act.	76	125	101	150	25	25	0	76	125
1.1.1.3		1.1.1.1		75	Act.	76	150	76	150	0	0	0	76	150
1.1.1.4	1.1.1.3	1.1.1.2		100	Act.	151	250	151	250	0	0	0	151	250
1.1.1.5	1.1.1.4			175	Act.	251	425	251	425	0	0	0	251	425
1.1.1.6	1.1.1.5			60	Act.	426	485	426	485	0	0	0	426	485
1.1.2					Proj.	486	925	1141	1580	655			486	925
1.1.2.1	1.1.1.6			75	Act.	486	560	1141	1215	655	0	0	486	560
1.1.2.2	1.1.2.1			100	Act.	561	660	1216	1315	655	0	0	561	660
1.1.2.3	1.1.2.1			75	Act.	561	635	1241	1315	680	0	0	561	635
1.1.2.4	1.1.2.2			175	Act.	661	835	1316	1490	655	0	0	661	835
1.1.2.5	1.1.2.3			175	Act.	636	810	1316	1490	680	25	0	636	810
1.1.2.6	1.1.2.5	1.1.2.4		90	Act.	836	925	1491	1580	655	0	0	836	925
1.2					DLI	486	1035	486	1035	0			486	1035
1.2.1					Proj.	486	1035	486	1035	0			486	1035
1.2.1.1		1.1.1.6		100	Act.	486	585	486	585	0	0	0	486	585
1.2.1.2	1.2.1.1			125	Act.	586	710	586	710	0	0	0	586	710
1.2.1.3	1.2.1.2			100	Act.	711	810	711	810	0	0	0	711	810
1.2.1.4	1.2.1.3			125	Act.	811	935	811	935	0	0	0	811	935
1.2.1.5	1.2.1.4			100	Act.	936	1035	936	1035	0	0	0	936	1035

Activity Code	Predecessors			Duration	Type	Scheduling						X (Lag)	Shifted Schedule	
	Pred. 1	Pred. 2	Pred. 3			ES	EF	LS	LF	TF	FF		Start	Finish
2					**R.A.**	**926**	**2030**	**1036**	**2030**	**0**			**926**	**2030**
2.1					DLI	1036	2030	1036	2030	0			1036	2030
2.1.1					Proj.	1036	1470	1036	1470	0			1036	1470
2.1.1.1		1.2.1.5		75	Act.	1036	1110	1036	1110	0	0	0	1036	1110
2.1.1.2	2.1.1.1			175	Act.	1111	1285	1136	1310	25	0	0	1111	1285
2.1.1.3		2.1.1.1		75	Act.	1111	1185	1111	1185	0	0	0	1111	1185
2.1.1.4	2.1.1.2			100	Act.	1286	1385	1311	1410	25	25	0	1286	1385
2.1.1.5	2.1.1.3			225	Act.	1186	1410	1186	1410	0	0	0	1186	1410
2.1.1.6	2.1.1.5	2.1.1.4		60	Act.	1411	1470	1411	1470	0	0	0	1411	1470
2.1.2					Proj.	1471	2030	1471	2030	0			1471	2030
2.1.2.1		2.1.1.6		75	Act.	1471	1545	1471	1545	0	0	0	1471	1545
2.1.2.2	2.1.2.1			125	Act.	1546	1670	1546	1670	0	0	0	1546	1670
2.1.2.3	2.1.2.2			75	Act.	1671	1745	1671	1745	0	0	0	1671	1745
2.1.2.4	2.1.2.3			100	Act.	1746	1845	1746	1845	0	0	0	1746	1845
2.1.2.5	2.1.2.4			125	Act.	1846	1970	1846	1970	0	0	0	1846	1970
2.1.2.6	2.1.2.5			60	Act.	1971	2030	1971	2030	0	0	0	1971	2030
2.2					DLI	926	1375	1581	2030	655			926	1375
2.2.1					Proj.	926	1375	1581	2030	655			926	1375
2.2.1.1	1.1.2.6			100	Act.	926	1025	1581	1680	655	0	0	926	1025
2.2.1.2	2.2.1.1			125	Act.	1026	1150	1681	1805	655	0	0	1026	1150
2.2.1.3	2.2.1.1			100	Act.	1026	1125	1831	1930	805	150	0	1026	1125
2.2.1.4	2.2.1.2			125	Act.	1151	1275	1806	1930	655	0	0	1151	1275
2.2.1.5	2.2.1.4	2.2.1.3		100	Act.	1276	1375	1931	2030	655	655	0	1276	1375

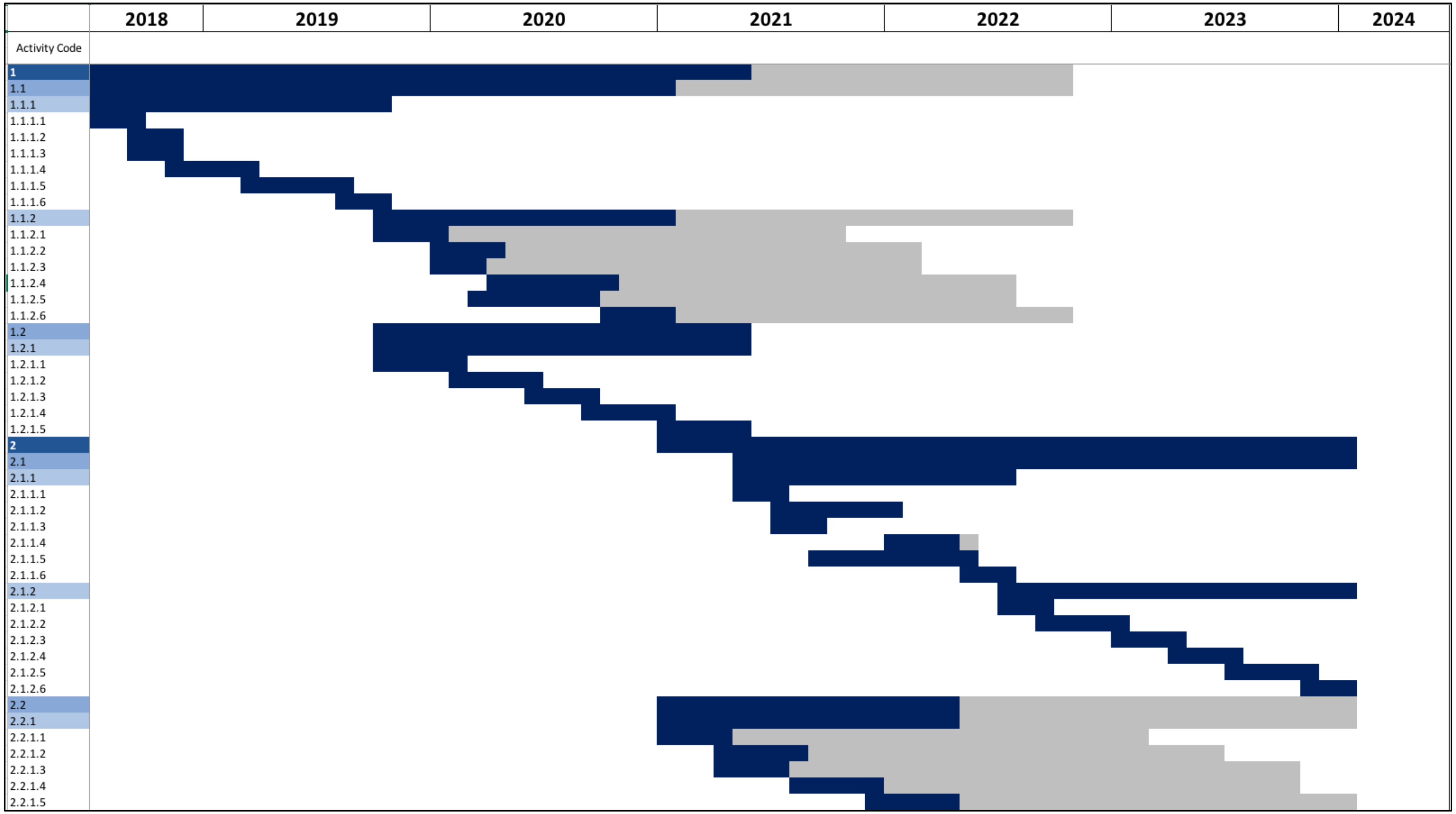

Figure 36: Program Bar Chart - Case Study

5 . 2 . 3 Cost Module

This module uses the inserted cost data of the program in devising all cost outputs from the model. These include (1) detailed cash flow requirements and dates for each activity, (2) overall cash in relationships with activities and their relative amounts, (3) detailed responsibilities of each program stakeholder and any transfers taking place throughout the program, (4) the effect of inflation on the program planning decisions, (5) a detailed daily cash flow schedule of all activities taking place throughout the program, (6) detailed cash flows for each of the program stakeholders, (7) calculations of lending bank fees and interest rates and (8) calculation of the program amortization schedule.

The cost module consists of four inter-connected sections, as shown in Figure 37. It starts by section A which sets the basis of calculations/costs for the whole module. Section A is represented in Table 12, Table 13 and Table 14. These tables set the bases for costs associated by all activities, projects and DLIs, and their respective dates. Section B uses these costs and their dates for drawing a cost loaded time schedule for the program. This schedule is then used in section C for calculating the cumulative daily costs for each stakeholder in the program. Based on the cash-in and cash-out of the financial management responsible stakeholder, Section D calculates the overall cash-flow spending of the government on the program and the required funding from the lending government on this program. This sets the basis for the calculations of the amortization schedule between both the government and the lending bank.

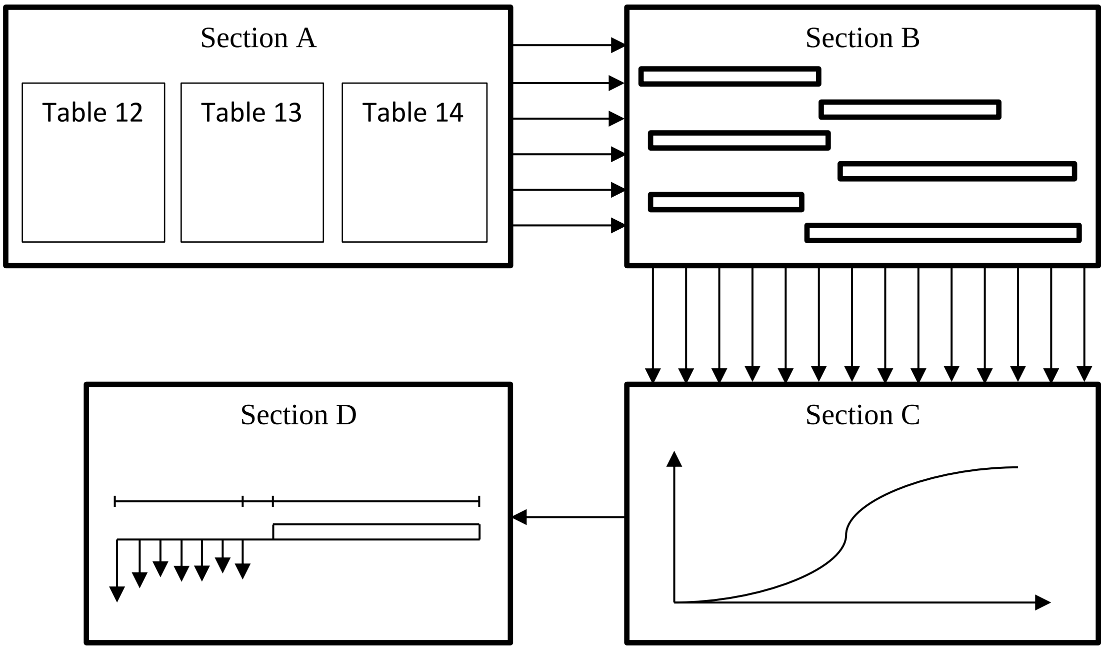

Figure 37: Cost Module Contents

Table 12 shows the detailed calculations of cash out amounts for each activity/project. This table considers time value of money, where the inflation rate defined by the user is added to each of the mentioned costs according to its duration from the program start date. It starts by getting the cash out details, as inserted by the user in the input module. This applies to the total cost, advance payment (amount or percentage), uniform payment, end payment, retention/delayed payment and delay period. The uniform payment at this stage considers both the advance payment received and the retention percentage, for each activity within projects. The specified inflation rate is added to the total costs of projects according to the duration between their start date and the start date of the program. The model then calculates the daily cost of the activity by dividing the uniform payment amount by the duration of the activity, to get the cost of the activity per day, which is then used for calculating the invoicing amounts at cut-off dates. Then the delayed payment date is calculated by adding the delay number of days to the finish date of the project. Then the advance payment amount by multiplying the advance payment percentage by the total amount of the project. Then the delayed amount is calculated by multiplying the delayed percentage by the total amount of the project.

Table 13 presents the calculation steps of the cash-in received by the government. This starts by getting the selected DLI alternative from the table of DLI alternatives mentioned earlier. In front of each DLI, it states the amount allocated for starting in the DLI execution, the finish amount, any repetitive payment and the repetition duration. It also lists activities that trigger payments, the amount received when achieving each activity and the finish date of that activity. In case of DLI 1.1, the government receives 14.98 million when starting in this DLI, while it receives 37.46 million when finishing it. No repetitive duration is set for this DLI. Three activities within this DLI trigger payments to the government when achieved. Activity 1.1.1.3 is finished on day 180 and triggers 7.49 million, same applies for activities 1.1.1.6 and 1.1.2.3.

Table 14 presents the responsibilities assigned for each activity/project. in this case no transfers between the main stakeholders A and other stakeholders B & C were defined. The last column in this table presents the inflation rate that is added to each activity cost. This is calculated as a compounding percentage based on the duration between the start date and the program start date. For example, the inflation percentage added on activity 1.1.1.6 is 3% as it exceeded one year from the start date of the program, while activity 1.2.1.4 includes inflation of 6.1% as it exceeded two years from the start of the program.

Table 12: Cost Module - Cash Out - Case study

Activity Code	Type	Schedule		Cost Data / Cash-Out									
		Start	Finish	Total cost	advance payment	uniform payment	end payment	delayed payment	delay Period	Daily cost	delay P. date	Advance	Delayed Am.
1	R.A.	1	1035										
1.1	DLI	1	925										
1.1.1	Proj.	1	485		20%			5%	365		850	12,060,000	3,015,000
1.1.1.1	Act.	1	75	10,000,000		7,500,000				101,351			
1.1.1.2	Act.	76	125	10,000,000		7,500,000				153,061			
1.1.1.3	Act.	76	150	10,000,000		7,500,000				101,351			
1.1.1.4	Act.	151	250	10,000,000		7,500,000				75,758			
1.1.1.5	Act.	251	425	10,000,000		7,500,000				43,103			
1.1.1.6	Act.	426	485	10,300,000		7,725,000				130,932			
1.1.2	Proj.	486	925		20%			5%	365		1290	12,421,800	3,105,450
1.1.2.1	Act.	486	560	10,300,000		7,725,000				104,392			
1.1.2.2	Act.	561	660	10,300,000		7,725,000				78,030			
1.1.2.3	Act.	561	635	10,300,000		7,725,000				104,392			
1.1.2.4	Act.	661	835	10,300,000		7,725,000				44,397			
1.1.2.5	Act.	636	810	10,300,000		7,725,000				44,397			
1.1.2.6	Act.	836	925	10,609,000		7,956,750				89,402			
1.2	DLI	486	1035										
1.2.1	Proj.	486	1035		20%			5%	365		1400	10,423,600	2,605,900
1.2.1.1	Act.	486	585	10,300,000		7,725,000				78,030			
1.2.1.2	Act.	586	710	10,300,000		7,725,000				62,298			
1.2.1.3	Act.	711	810	10,300,000		7,725,000				78,030			
1.2.1.4	Act.	811	935	10,609,000		7,956,750				64,167			

Activity Code	Type	Schedule		Cost Data / Cash-Out									
		Start	Finish	Total cost	advance payment	uniform payment	end payment	delayed payment	delay Period	Daily cost	delay P. date	Advance	Delayed Am.
1.2.1.5	Act.	936	1035	10,609,000		7,956,750				80,371			
2	**R.A.**	**926**	**2030**										
2.1	DLI	1036	2030										
2.1.1	Proj.	1036	1470										
2.1.1.1	Act.	1036	1110	10,609,000	5,304,500		5,304,500					5,304,500	
2.1.1.2	Act.	1111	1285	10,927,270	5,463,635		5,463,635					5,463,635	
2.1.1.3	Act.	1111	1185	10,927,270	5,463,635		5,463,635					5,463,635	
2.1.1.4	Act.	1286	1385	10,927,270	5,463,635		5,463,635					5,463,635	
2.1.1.5	Act.	1186	1410	10,927,270	5,463,635		5,463,635					5,463,635	
2.1.1.6	Act.	1411	1470	10,927,270	5,463,635		5,463,635					5,463,635	
2.1.2	Proj.	1471	2030		15%			5%	365		2395	10,230,875	3,410,292
2.1.2.1	Act.	1471	1545	11,255,088		9,004,070				121,677			
2.1.2.2	Act.	1546	1670	11,255,088		9,004,070				72,613			
2.1.2.3	Act.	1671	1745	11,255,088		9,004,070				121,677			
2.1.2.4	Act.	1746	1845	11,255,088		9,004,070				90,950			
2.1.2.5	Act.	1846	1970	11,592,741		9,274,193				74,792			
2.1.2.6	Act.	1971	2030	11,592,741		9,274,193				157,190			
2.2	DLI	926	1375										
2.2.1	Proj.	926	1375		15%			5%	365		1740	13,669,697	4,556,566
2.2.1.1	Act.	926	1025	21,218,000		16,974,400				171,459			
2.2.1.2	Act.	1026	1150	21,218,000		16,974,400				136,890			
2.2.1.3	Act.	1026	1125	15,913,500		12,730,800				128,594			
2.2.1.4	Act.	1151	1275	16,390,905		13,112,724				105,748			
2.2.1.5	Act.	1276	1375	16,390,905		13,112,724				132,452			

Table 13: Cost module - Cash In - Case Study

Activity Code	Cash-In												
	DLI Data				Milestone payments								
	Start Amount	Finish Amount	repetitive pay.	Repet. Dur.	Activity 1	Act.1 Paym	Act.1 Amount	Activity 2	Act.2 Paym.	Act.2 Amount	Activity 3	Act.3 Paym.	Act.3 Amount
1													
1.1	14,987,469	37,468,672			1.1.1.3	180	7,493,734	1.1.1.6	515	7,493,734	1.1.2.3	665	7,493,734
1.1.1													
1.1.1.1													
1.1.1.2													
1.1.1.3													
1.1.1.4													
1.1.1.5													
1.1.1.6													
1.1.2													
1.1.2.1													
1.1.2.2													
1.1.2.3													
1.1.2.4													
1.1.2.5													
1.1.2.6													
1.2	3,746,867	18,734,336			1.2.1.2	740	7,493,734	1.2.1.4	965	7,493,734			
1.2.1													
1.2.1.1													

Activity Code	Cash-In												
	DLI Data				Milestone payments								
	Start Amount	Finish Amount	repetitive pay.	Repet. Dur.	Activity 1	Act.1 Paym	Act.1 Amount	Activity 2	Act.2 Paym.	Act.2 Amount	Activity 3	Act.3 Paym.	Act.3 Amount
1.2.1.2													
1.2.1.3													
1.2.1.4													
1.2.1.5													
2													
2.1	7,493,734	37,468,672			2.1.1.3	1215	7,493,734	2.1.1.6	1500	7,493,734	2.1.2.3	1775	7,493,734
2.1.1													
2.1.1.1													
2.1.1.2													
2.1.1.3													
2.1.1.4													
2.1.1.5													
2.1.1.6													
2.1.2													
2.1.2.1													
2.1.2.2													
2.1.2.3													
2.1.2.4													
2.1.2.5													
2.1.2.6													
2.2	3,746,867	26,228,070			2.2.1.2	1180	6,931,704	2.2.1.4	1305	7,493,734			
2.2.1													
2.2.1.1													
2.2.1.2													

Activity Code	Cash-In												
	DLI Data				Milestone payments								
	Start Amount	Finish Amount	repetitive pay.	Repet. Dur.	Activity 1	Act.1 Paym	Act.1 Amount	Activity 2	Act.2 Paym.	Act.2 Amount	Activity 3	Act.3 Paym.	Act.3 Amount
2.2.1.3													
2.2.1.4													
2.2.1.5													

Table 14: Cost Module - Responsibilities & inflation - Case study

	Transfers				
Activity Code	**Responsible**	**Recipient**	**Transfer**	**Payee**	**Inflation**
1					**1.000**
1.1					1.000
1.1.1	B				1.000
1.1.1.1	B				1.000
1.1.1.2	B				1.000
1.1.1.3	B				1.000
1.1.1.4	B				1.000
1.1.1.5	B				1.000
1.1.1.6	B				1.030
1.1.2	C				1.030
1.1.2.1	C				1.030
1.1.2.2	C				1.030
1.1.2.3	C				1.030
1.1.2.4	C				1.030
1.1.2.5	C				1.030
1.1.2.6	C				1.061
1.2					1.030
1.2.1	A				1.030
1.2.1.1	A				1.030
1.2.1.2	A				1.030
1.2.1.3	A				1.030
1.2.1.4	A				1.061
1.2.1.5	A				1.061
2					**1.061**
2.1					1.061
2.1.1	A				1.061
2.1.1.1	A				1.061
2.1.1.2	A				1.093
2.1.1.3	A				1.093
2.1.1.4	A				1.093
2.1.1.5	A				1.093
2.1.1.6	A				1.093
2.1.2	A				1.126
2.1.2.1	A				1.126
2.1.2.2	A				1.126
2.1.2.3	A				1.126
2.1.2.4	A				1.126
2.1.2.5	A				1.159
2.1.2.6	A				1.159
2.2					1.061
2.2.1	A				1.061

	Transfers				
Activity Code	**Responsible**	**Recipient**	**Transfer**	**Payee**	**Inflation**
2.2.1.1	A				1.061
2.2.1.2	A				1.061
2.2.1.3	A				1.061
2.2.1.4	A				1.093
2.2.1.5	A				1.093

After calculating all costs and their relevant dates, costs are plotted on a daily schedule, each row in this schedule represents one of the program activities, as shown in Table 12. Each column in this schedule represents a day in the program life cycle. Each day in-front of each activity, the model checks if there is any amount allocated for cash-out (from Table 12) or cash-in (from Table 13). For example, in day 1 of the program, stakeholder B has to pay an amount of 12.06 million as an advance payment for project 1.1.1, also the government receives the advance payment allocated for the program. This applies to all cash-in and cash-out amounts. This schedule is considered a cost-loaded time schedule that serves as a tool for calculating daily costs/income throughout the program.

Based on this cost-loaded schedule, three different s-curves are plotted for the three program stakeholders. For example, stakeholder B is responsible for project 1.1.1, so any cash-out amounts relevant to this project are added to the amounts spent by stakeholder B. Same applies for stakeholder C. These two stakeholders are the ones supposed to have zero spending on the program, so stakeholder A makes semi-annual transfers for them to cover their planned expenses during the future six months period. These amounts are calculated based on the cash-out amounts previously mentioned.

Table 15 describes the method of calculating the cumulative curves amounts. It starts by calculating the amounts of cash-out directly paid by each stakeholder for activities under their responsibility. So, stakeholders B & C, have the cash-out for activities per day added in their respective rows in the first section of the table (cash-out rows of stakeholders B & C). Based on these amounts and the specified transfers duration, the model calculates the cash-in amounts for each stakeholder by adding the amounts spent by this stakeholder during each six-months period and setting it as a transfer from stakeholder A at the beginning of such period. For example, at the first six months of the program, the project under the responsibility of stakeholder B starts in execution, so stakeholder B spends 37.04 million on this project through that period. This amount is set as a transfer from stakeholder A to stakeholder B at the beginning of the program.

As for stakeholder A, cash-out is calculated by adding the amounts spent on its projects and the amounts for semi-annual transfers made to other stakeholders. Cash-in amounts for stakeholder A represent the scheduled DLI transfers from the bank to the government. Cumulative costs are calculated as build-ups from the daily total amounts calculated in the beginning of the table. These are calculated to get the overall spending of all program stakeholders. For stakeholder A, it calculates the amount of spending required by the government on the program while for stakeholders B & C, it ensures they always have zero spending on the program. At the end of the table, the expenditure of each stakeholder is calculated. This is the difference between cash-in received and the cash-out spent by each stakeholder.

After calculating all cumulative amounts and expenditures, the model calculates the amounts set for the commitment fees to be paid by the government to the bank. This amount is calculated semi-annually. Every six months period the model subtracts the cumulative borrowed amounts from the total loan amount to get the undisbursed balance and multiplies this amount by the commitment fee percentage.

Table 15: Cumulative Amounts calculation

Date		1	2	3	…	…	…	…	T
Daily Total Amounts									
A	Cash-In								
	Cash-Out								
B	Cash-In								
	Cash-Out								
C	Cash-In								
	Cash-Out								
Cumulative Costs									
A	Cash-In								
	Cash-Out								
B	Cash-In								
	Cash-Out								
C	Cash-In								
	Cash-In								
Expenditure									
A									
B									
C									
Commitment fee Calculation									
Amount									

Figure 38 shows the cash flow diagram of stakeholder A, which is the government financial and technical management entity. This stakeholder is responsible for the overall financial management of the program. This means that this stakeholder is responsible for covering the full expenses of the program while managing the financial relationship with the lending bank. As shown on the cash flow, stakeholder A receives the advance payment of 25% previously set in the model and starts in financing the program. The cash-in curve consists of steps as the government receives disbursements from the bank through installments and not continuous payments. Whenever a new result is achieved and verified the bank pays the government its allocated amount. In case of the cash out curve, it consists of both steps and connecting curves. Steps in this curve represent the semi-annual transfers from the government to other stakeholders, while curves represent the daily spending of the government on its own managed activities. In this case study, the government starts in spending on the program starting from the middle of year 2019, when the cumulative cash-in curve becomes lower than the cumulative cash-out curve. The maximum amount of spending made by the government on the program is 135 million and appears in March 2024. Figure 39 shows the spending profile of stakeholder A, which represents the government spending. It starts by a negative amount, caused by the advance payment received from the bank, then starts increasing until it reaches the maximum amount of spending. Throughout the program duration, the overall spending amount has sudden decreases due to the amounts received from the bank. The minimization of this amount is one of the main objective functions of this model.

In case of both stakeholders B and C, the financial management of this program requires that the cumulative cash-in curve is always above the cumulative cash-out curve. This is ensured by planning the semi-annual transfers from stakeholder A to other stakeholders (B & C) that cover their expenses through that period. This is shown in Figure 40 and Figure 41, where the dashed curves represent the cumulative cash-in curves received from stakeholder A, while straight curves represent cash-out. In case of stakeholder B, Stakeholder A makes a transfer of nearly 37 million that covers the expenses of stakeholder B throughout the first six months period of the program. After this period ends, stakeholder A makes another transfer to cover spending during the next six-months period. This continues until all activities under the responsibility of stakeholder B are finished, as shown in Figure 40 in the middle of year 2020.

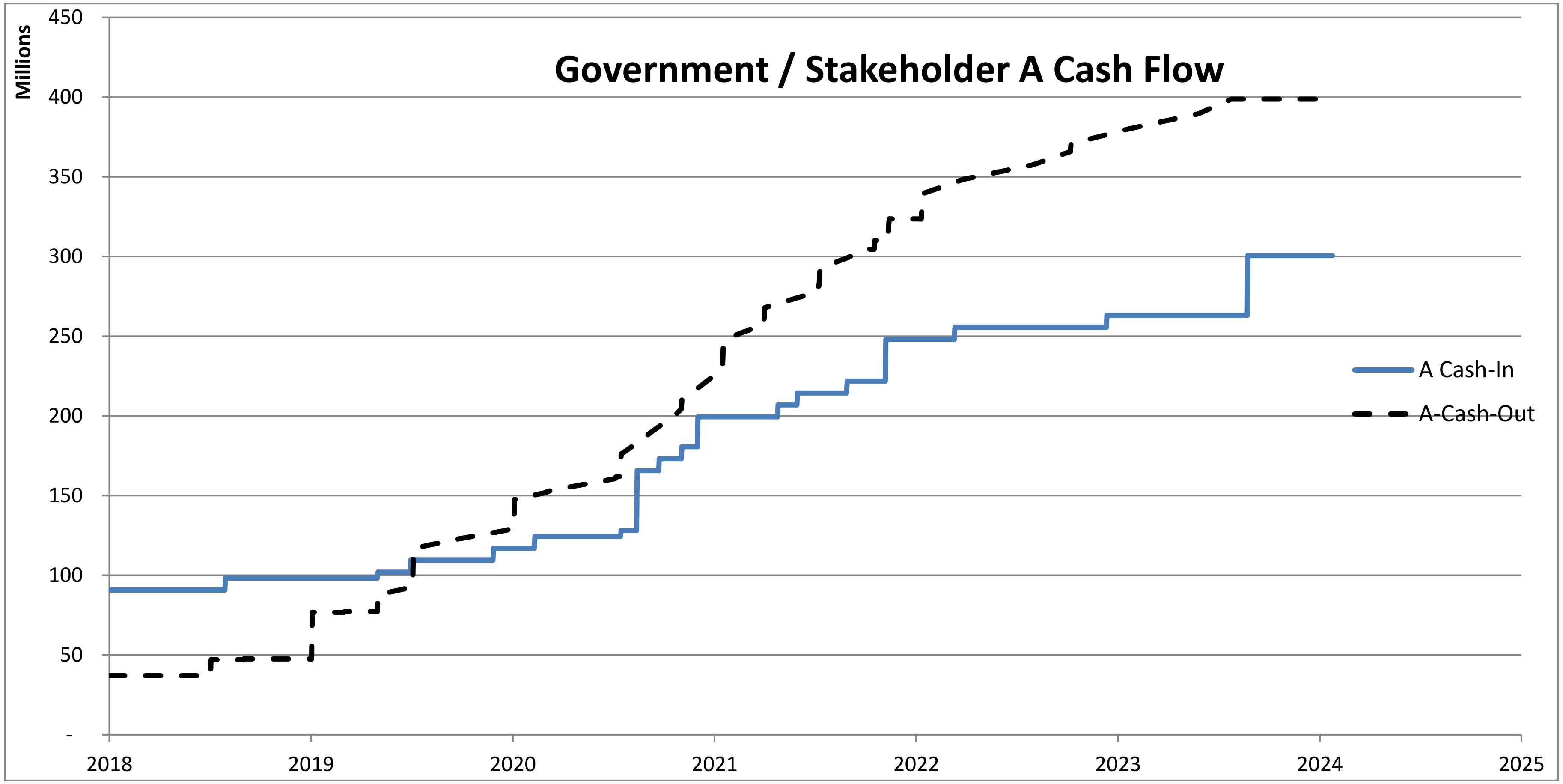

Figure 38: Stakeholder A - Cash Flow

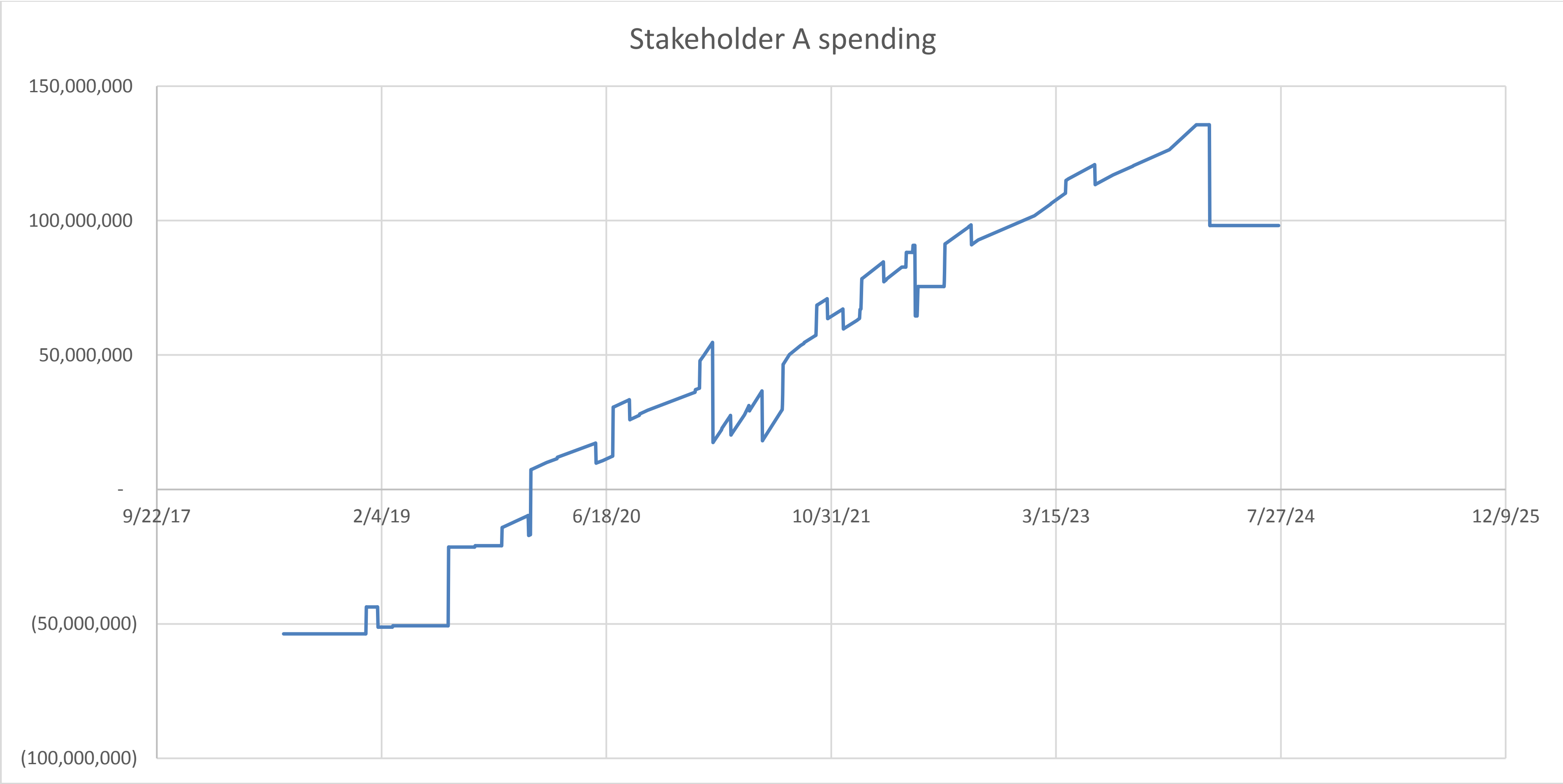

Figure 39: Stakeholder A spending profile

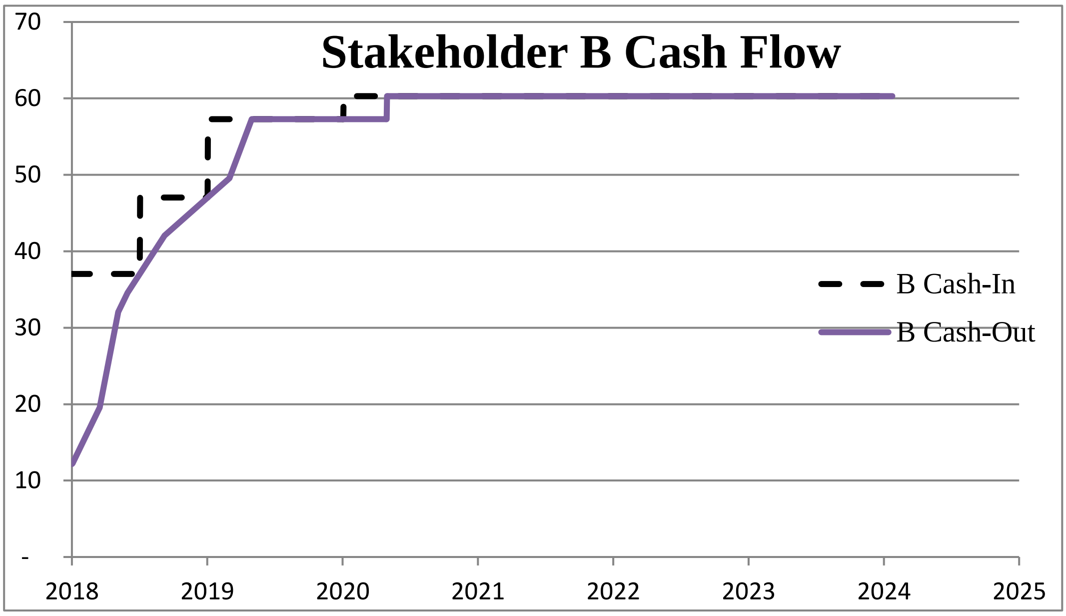

Figure 40: Stakeholder B cash flow

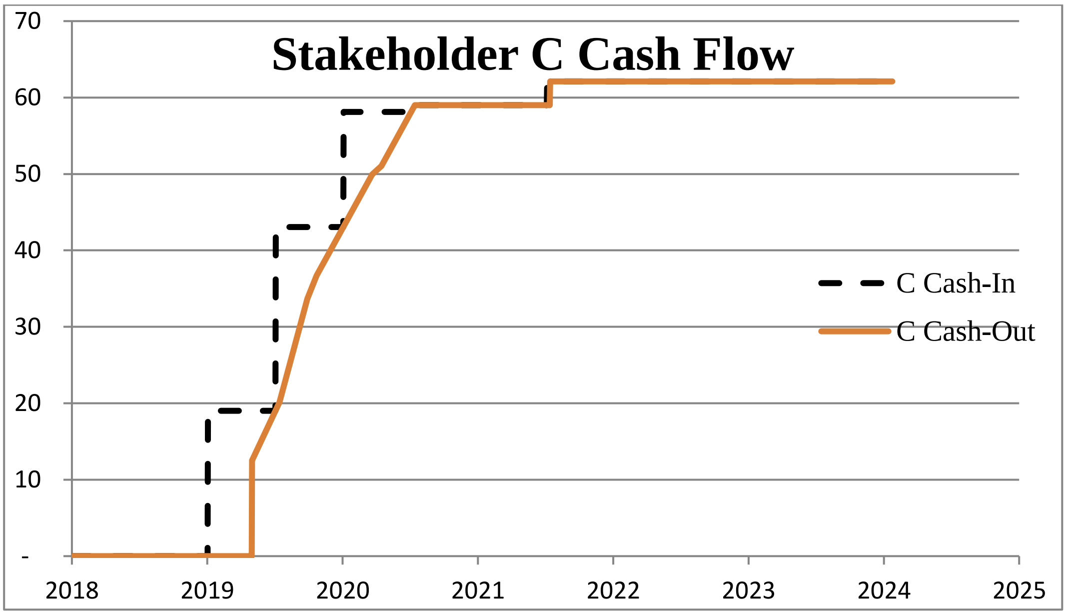

Figure 41: Stakeholder C cash flow

After calculating all the cash flow requirements of the program based on the planned schedule, the model starts in calculating the amortization schedule based on the preset durations and dates. In this case, the interest rate duration is set to be each six months. So, the amounts borrowed from the bank are added in the beginning of each six months period to form the borrowed amounts period cash flow. Table 16 shows the amounts disbursed to the government during each of the six-months periods starting at the dates described in the table. It starts by the advance payment amount, front-end fee amount and an amount set at the beginning of one of the projects that start at the beginning of the program, as shown in the July 2018 date. The government did not achieve any DLIs throughout this 6-months period, so these were the only amounts calculated during this period. This table is the basis for the calculation of the amortization schedule.

Table 16: 6-months disbursement schedule

Date	Amounts Disbursed
Jul-18	90,737,469
Jan-18	7,493,734
Jul-19	11,240,602
Jan-20	7,493,734
Jul-20	7,493,734
Jan-21	74,937,343
Jul-21	14,425,439
Jan-22	33,721,805
Jul-22	7,493,734
Jan-23	7,493,734
Jul-23	
Jan-24	37,468,672

The future worth of the amounts described in Table 16 is calculated at the finish date of the program, at the end of the five year period of the program and the beginning of loan return period, as this program did not include a grace period. This is done using the interest rate defined in the input module, 1.5% compounded semi-annually. After getting this amount, a uniform amount, that represents the installment amount, equivalent to this amount is calculated over the 30 years period, as shown in Figure 42. This is the second number that this model considers in the optimization process.

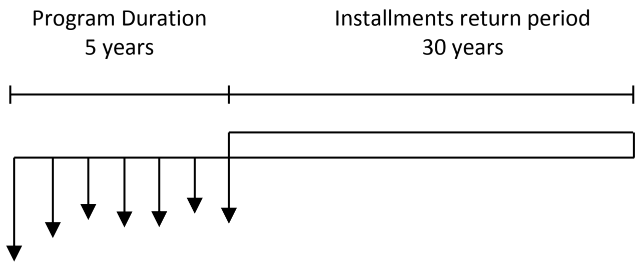

Figure 42: Program Cash Flow (Amortization schedule)

After calculating all cash-in and cash-out requirements of the program, the model presents the outputs of these calculations in a table format for the user, as shown in Table 17. This table presents all program financial transfers on a monthly basis for the government throughout the program life-cycle. This table is also a part of the output module. All amounts presented in this table are average monthly amounts. This table starts by monthly dates for each of the calculated costs, then the monthly cash-in amounts received from the bank. Then the cumulative cash-in amounts, monthly and cumulative cash-out amounts, overall finance amount during the month through subtracting the cumulative cash-out amount from the cumulative cash-in amount, this results in the overall amount that the government spends on the program at that date. Any negative amounts in this column reflect a month that the government has a surplus amount on account of the program. Finally, the monthly finance amount, which is the amount that the government has to provide finance for the program at that month. This amount is calculated by subtracting the finance amount at that month from the finance amount in the month before. As shown in March 2020, the monthly finance amount is

2.345 Mn that is the finance amount at that month (11.98 Mn) minus the finance amount in February 2020 (9.64 Mn).

The average of all monthly finance amounts calculated in the program is considered in the optimization process as this forces the model to optimize spending on the program without increasing the monthly finance amounts spent by the government on the program. This is because when optimizing the other two objectives only, which are to minimize the finance amount and the returned installments, the model may solve this problem by increasing the monthly finance amounts.

Table 17: Program Monthly Balance

Date	Cash-In	Cumulative Cash-In	Cash-Out	Cumulative Cash-Out	Finance (Average)	Monthly Finance
07/2018	90,737,469	(90,737,469)	37,035,000	37,035,000	(53,702,469)	
08/2018		(90,737,469)		37,035,000	(53,702,469)	
09/2018		(90,737,469)		37,035,000	(53,702,469)	
10/2018		(90,737,469)		37,035,000	(53,702,469)	
11/2018		(90,737,469)		37,035,000	(53,702,469)	
12/2018		(90,737,469)		37,035,000	(53,702,469)	
01/2019	7,493,734	(90,737,469)	9,996,429	47,031,429	(43,706,040)	
02/2019		(98,231,203)		47,031,429	(51,199,774)	
03/2019		(98,231,203)	504,422	47,535,851	(50,695,352)	
04/2019		(98,231,203)		47,535,851	(50,695,352)	
05/2019		(98,231,203)		47,535,851	(50,695,352)	
06/2019		(98,231,203)		47,535,851	(50,695,352)	
07/2019		(98,231,203)	29,267,371	47,535,851	(50,695,352)	
08/2019		(98,231,203)	504,422	76,803,222	(21,427,981)	
09/2019		(98,231,203)		77,307,644	(20,923,559)	
10/2019	3,746,867	(98,231,203)	10,578,100	77,307,644	(20,923,559)	
11/2019		(101,978,070)	2,317,500	87,962,994	(14,015,076)	
12/2019	7,493,734	(101,978,070)	2,394,750	90,280,494	(11,697,576)	
01/2020		(109,471,805)	26,437,893	92,675,244	(16,796,561)	
02/2020		(109,471,805)	1,884,900	119,113,137	9,641,332	9,641,332
03/2020		(109,471,805)	2,392,120	121,458,907	11,987,103	2,345,770
04/2020		(109,471,805)	1,854,000	123,374,707	13,902,903	1,915,800
05/2020	7,493,734	(109,471,805)	1,915,800	125,228,707	15,756,903	1,854,000
06/2020		(116,965,539)	2,163,000	127,144,507	10,178,968	-
07/2020		(116,965,539)	20,472,274	129,322,957	12,357,418	2,178,450
08/2020	7,493,734	(116,965,539)	2,833,602	149,795,231	32,829,692	20,472,274
09/2020		(124,459,273)	2,154,348	152,628,833	28,169,560	-
10/2020		(124,459,273)	1,973,274	154,769,585	30,310,312	2,140,752

Date	Cash-In	Cumulative Cash-In	Cash-Out	Cumulative Cash-Out	Finance (Average)	Monthly Finance
11/2020		(124,459,273)	1,909,620	156,742,859	32,283,586	1,973,274
12/2020		(124,459,273)	1,973,274	158,652,479	34,193,206	1,909,620
01/2021	3,746,867	(124,459,273)	20,081,069	160,625,753	36,166,480	1,973,274
02/2021	37,468,672	(128,206,140)	6,980,722	180,892,479	52,686,339	16,519,859
03/2021	7,493,734	(165,674,812)	8,064,469	187,873,201	22,198,389	-
04/2021		(173,168,546)	8,319,578	195,937,671	22,769,124	570,735
05/2021	26,228,070	(173,168,546)	13,540,267	204,350,608	31,182,061	8,412,937
06/2021		(199,396,617)	7,893,096	217,811,307	18,414,690	-
07/2021		(199,396,617)	24,260,661	225,704,403	26,307,786	7,893,096
08/2021		(199,396,617)	3,993,397	249,837,756	50,441,140	24,133,353
09/2021		(199,396,617)	14,325,832	254,051,769	54,655,152	4,214,012
10/2021	6,931,704	(199,396,617)	3,251,956	268,126,092	68,729,476	14,074,324
11/2021	7,493,734	(206,328,321)	3,147,054	271,378,048	65,049,727	-
12/2021		(213,822,055)	3,356,857	274,525,102	60,703,046	-
01/2022		(213,822,055)	18,097,664	277,908,184	64,086,129	3,383,083
02/2022	7,493,734	(213,822,055)	3,671,563	296,005,849	82,183,794	18,097,664
03/2022		(221,315,789)	4,261,655	299,677,412	78,361,622	-
04/2022		(221,315,789)	6,250,398	303,939,067	82,623,277	4,261,655
05/2022	26,228,070	(221,315,789)	13,533,170	312,664,238	91,348,448	8,725,171
06/2022		(247,543,860)	-	323,591,508	76,047,648	-
07/2022		(247,543,860)	18,215,650	323,591,508	76,047,648	-
08/2022		(247,543,860)	3,721,682	341,927,212	94,383,352	18,335,704
09/2022	7,493,734	(247,543,860)	3,396,617	345,648,894	98,105,035	3,721,682
10/2022		(255,037,594)	2,233,009	348,997,489	93,959,895	-
11/2022		(255,037,594)	2,160,977	351,230,499	96,192,905	2,233,009
12/2022		(255,037,594)	2,233,009	353,391,476	98,353,882	2,160,977
01/2023		(255,037,594)	2,473,118	355,624,485	100,586,891	2,233,009
02/2023		(255,037,594)	3,361,520	358,145,625	103,108,031	2,521,140
03/2023		(255,037,594)	3,834,088	361,507,144	106,469,550	3,361,520
04/2023		(255,037,594)	7,587,936	365,341,233	110,303,639	3,834,088
05/2023		(255,037,594)	2,791,262	372,899,155	117,861,561	7,557,922
06/2023	7,493,734	(255,037,594)	2,701,221	375,690,417	120,652,823	2,791,262
07/2023		(262,531,328)	2,616,943	378,391,638	115,860,310	-
08/2023		(262,531,328)	2,300,000	380,992,734	118,461,406	2,601,096
09/2023		(262,531,328)	2,319,478	383,292,734	120,761,406	2,300,000
10/2023		(262,531,328)	2,300,000	385,612,212	123,080,883	2,319,478
11/2023		(262,531,328)	2,868,817	387,912,212	125,380,883	2,300,000
12/2023		(262,531,328)	4,791,666	390,861,405	128,330,076	2,949,193
01/2024		(262,531,328)	3,245,967	395,653,071	133,121,743	4,791,666
02/2024	37,468,672	(262,531,328)	-	398,744,468	136,213,140	3,091,398
03/2024		(300,000,000)	-	398,744,468	98,744,468	-

5 . 2 . 4 Optimization Module

The optimization module prepares the optimization settings for running the genetic algorithms optimization process. In this case, the full capabilities of the model are tested. The model simulates optimization parameters, such as variables, constraints and objective function. The set of variables considered in this case are : (1) durations of activities, which can change between the minimum possible duration and the maximum possible duration throughout the optimization process, while having to be an integer number of days, (2) floats of activities, which can change by adding a lag duration before activities for moving them within their available floats without affecting the overall duration of the program, this lag duration has to be an integer number of days too and (3) the selection of the optimum DLI payment method based on the defined alternatives.

The set of constraints defined in this case are (1) the milestones that have to be considered while planning the program, where all relationships of the program activities and their respective dates are confirmed and (2) a check that lags do not affect the program scheduling logic is confirmed. The objective function of this model is to minimize a combined amount between the three parameters considered in this model which are (1) the maximum spending of the government on the program, (2) the amount of each loan installment paid by the government to the bank and (3) the average monthly spending of the government on the program.

Table 18 shows the main settings of the optimization module in this case study. For each activity, the table shows its minimum duration, maximum duration and the average duration that each activity most commonly would take. Then the duration that the model selects for this activity (between the minimum and maximum durations). The total float and the free float are continuously updated based on changes in the durations of activities. The table then includes the lag duration selected for each activity. This lag continuously changes throughout the optimization process and reflects on the time schedule calculated in the scheduling module. A check is then performed that the lag amounts do not exceed the original float amounts, this ensures that activities that are not on the critical path only move within their available float. This check gives results of only zero and one, where zero represents that activities are within their float while one reports the opposite. Then the table sets the limits for the lag amounts available for each activity. As shown in the table, minimum and maximum lag amounts are set only for activities as calculations of other projects, DLIs and R.A.s depend mainly on their activities.

Table 18: Optimization Settings

	Durations									
Activity Code	Min. Dur.	Avg. Dur.	Max Dur.	Duration	TF	FF	X (Lag)	Check	Min (Lag)	Max Lag
1	**0**	**0**	**0**	**0**	**545**		**0**	**0**	**0**	**0**
1.1	0	0	0	0	655		0	0	0	0
1.1.1	0	0	0	0	0		0	0	0	0
1.1.1.1	50	75	100	75	0	0	0	0	0	0
1.1.1.2	25	50	75	50	25	25	0	0	0	25
1.1.1.3	50	75	100	75	0	0	0	0	0	0
1.1.1.4	75	100	125	100	0	0	0	0	0	0
1.1.1.5	150	175	200	175	0	0	0	0	0	0
1.1.1.6	50	60	75	60	0	0	0	0	0	0
1.1.2	0	0	0	0	655		0	0	0	0
1.1.2.1	50	75	100	75	655	0	0	0	0	655
1.1.2.2	50	100	125	100	655	0	0	0	0	655
1.1.2.3	60	75	100	75	680	0	0	0	0	680
1.1.2.4	150	175	200	175	655	0	0	0	0	655
1.1.2.5	150	175	200	175	680	25	0	0	0	680
1.1.2.6	75	90	100	90	655	0	0	0	0	655
1.2	0	0	0	0	0		0	0	0	0
1.2.1	0	0	0	0	0		0	0	0	0
1.2.1.1	75	100	125	100	0	0	0	0	0	0
1.2.1.2	100	125	150	125	0	0	0	0	0	0
1.2.1.3	75	100	125	100	0	0	0	0	0	0
1.2.1.4	100	125	150	125	0	0	0	0	0	0
1.2.1.5	75	100	125	100	0	0	0	0	0	0
2	**0**	**0**	**0**	**0**	**0**		**0**	**0**	**0**	**0**
2.1	0	0	0	0	0		0	0	0	0
2.1.1	0	0	0	0	0		0	0	0	0
2.1.1.1	50	75	100	75	0	0	0	0	0	0
2.1.1.2	150	175	200	175	25	0	0	0	0	25
2.1.1.3	50	75	100	75	0	0	0	0	0	0
2.1.1.4	75	100	125	100	25	25	0	0	0	25
2.1.1.5	200	225	250	225	0	0	0	0	0	0
2.1.1.6	50	60	75	60	0	0	0	0	0	0

	Durations									
Activity Code	Min. Dur.	Avg. Dur.	Max Dur.	Duration	TF	FF	X (Lag)	Check	Min (Lag)	Max Lag
2.1.2	0	0	0	0	0		0	0	0	0
2.1.2.1	50	75	100	75	0	0	0	0	0	0
2.1.2.2	100	125	150	125	0	0	0	0	0	0
2.1.2.3	50	75	100	75	0	0	0	0	0	0
2.1.2.4	75	100	125	100	0	0	0	0	0	0
2.1.2.5	100	125	150	125	0	0	0	0	0	0
2.1.2.6	50	60	75	60	0	0	0	0	0	0
2.2	0	0	0	0	655		0	0	0	0
2.2.1	0	0	0	0	655		0	0	0	0
2.2.1.1	75	100	125	100	655	0	0	0	0	655
2.2.1.2	100	125	150	125	655	0	0	0	0	655
2.2.1.3	75	100	125	100	805	150	0	0	0	805
2.2.1.4	100	125	150	125	655	0	0	0	0	655
2.2.1.5	75	100	125	100	655	655	0	0	0	655

The next stage is the selection of the near optimum DLI for the program. A table similar to Table 10 is used for selecting among the available DLI options. Table 20 presents the criteria used for the selection among DLIs, while Table 19 presents the method that the model uses for changing alternatives and selecting among the available alternatives. This table presents the number of alternatives available for each DLI and then the DLI that is selected among them.

Table 19: DLI selection method

#	Alternatives	Selection
1.1	2	1
1.2	2	1
2.1	3	1
2.2	2	1

Table 20: DLI alternative selection

#	Selection	Alt.	Total Amount	Distribution	Start Amount	Repetitive payment	Repetition duration	Activity 1	Act.1 Amount	Activity 2	Act.2 Amount	Activity 3	Act.3 Amount	Finish Amount
1.1	1.1	1	100,000,000	T & S	20,000,000			1.1.1.3	10,000,000	1.1.1.6	10,000,000	1.1.2.3	10,000,000	50,000,000
1.1		2	100,000,000	T & S	10,000,000			1.1.1.3	8,000,000	1.1.1.6	7,000,000	1.1.2.3	10,000,000	65,000,000
1.2	1.2	1	50,000,000	T & S	5,000,000			1.2.1.2	10,000,000	1.2.1.4	10,000,000			25,000,000
1.2		2	50,000,000	T & S	8,000,000			1.2.1.2	7,500,000	1.2.1.4	7,500,000			27,000,000
2.1	2.1	1	90,000,000	T & S	10,000,000			2.1.1.3	10,000,000	2.1.1.6	10,000,000	2.1.2.3	10,000,000	50,000,000
2.1		2	90,000,000	T & S	20,000,000			2.1.1.3	9,000,000	2.1.1.6	8,000,000	2.1.2.3	8,000,000	45,000,000
2.1		3	90,000,000	T & S	30,000,000			2.1.1.3	8,000,000	2.1.1.6	6,000,000	2.1.2.3	6,000,000	40,000,000
2.2	2.2	1	59,250,000	T & S	5,000,000			2.2.1.2	9,250,000	2.2.1.4	10,000,000			35,000,000
2.2		2	59,250,000	T & S	8,000,000			2.2.1.2	4,250,000	2.2.1.4	5,000,000			42,000,000

After setting variables, constraints are added in the model. The main constraint is the set of milestones. Table 21 presents the set of milestones defined earlier. The last two columns of the table include both the actual values for the dates of milestones. Based on the defined relationship of the defined milestone and the activity, the check in the last column of the table confirms if the program abides by all of the defined milestones or not. If any of the milestones is not satisfied, this column changes the value from zero to one. The sum of all values of the check amount has to always be zero.

Table 21: Milestone Check

	Description	Date	Related Item	Relation	Actual	Check
M.1	Start Date	0	Start	Start	0	0
M.2	Finish Date	2100	Finish	Finish	2030	0
M.3	Project 1.1.2 Finish	1200	1.1.2	Finish	925	0
M.4	Project 1.2.1 Finish	1200	1.2.1	Finish	1035	0

This model considers multiple objectives for providing a realistic near optimum solution. These include the minimization of: (1) the maximum spending of the government on the program, that is 136 million, (2) the loan installment paid by the government, that is 11.08 million and (3) the average monthly spending of the government on the program, that is 2.85 million. The overall objective function in this case is the multiplication of the above three values, this follows the weighted product method for considering multiple objectives (Marler & Arora, 2004); however, no weights were considered due to the equal importance of the three objectives. The main objective of this model is to minimize this overall objective function, for providing a near optimum combination of their values. Table 22 summarizes the presentation of the model objectives. As shown in the table, the multiple objective value is equal to the multiplication of other values, while being divided by 10^{15} for obtaining a small number that helps in judging the overall effect of the model.

Table 22: Multiple Objectives table

Objective	Value
Maximum Expenditure	136,213,140
Loan Installment	11,080,678
Average Monthly Expenses	2,858,147
Overall Objective Function	43,138

After setting all calculations for the optimization process, Evolver Add-in is used for applying Genetic Algorithms (GA) optimization on this problem. Figure 43 presents the interface of Evolver that is used for defining optimization settings. It starts by the definition of the optimization goal, which is to minimize the cell that has the "Overall Objective Function" shown in Table 22.

The set of variables are then defined in the interface as the "Adjustable Cell Ranges". For each set of variables (range), a minimum, maximum and value type (integer or fraction) is defined. (1) The first set of variables is the lag duration (X) shown in Table 18, the minimum amount for each of the lag amounts is defined to be zero while the maximum amount is set to be equal to the total float of each activity (cell range L27:L72). These amounts are set to be integers, as they represent numbers of days. (2) The second set of variables is the number of DLI alternatives available for each DLI, as shown in Table 19. The minimum amount for each DLI is always set to be one and the maximum is the total number of DLI alternatives available for that DLI (cell range AF5:AF8). These amounts are set to be integers, as they represent numbers of DLIs. (3) The third set of variables is the duration set for each activity, as shown in Table 18. The minimum and maximum durations for each activity are set to the amounts defined earlier by the user (cell range I27:I72). These amounts are set to be integers, as they represent numbers of days.

Two constraints are defined in this model, (1) the first constraint is the scheduling logic of the program. This is ensured by adding all values in the check column in Table 18 to be equal to zero. All amounts in the “Check” column are added in cell “M25”, and this cell is set to be equal to zero. (2) The second constraint is the check that the program abides by all the milestones defined. The total value of the “Check” column in Table 21, is calculated in cell “Y4”. This cell has to be equal to zero. Both of these constraints are hard constraints.

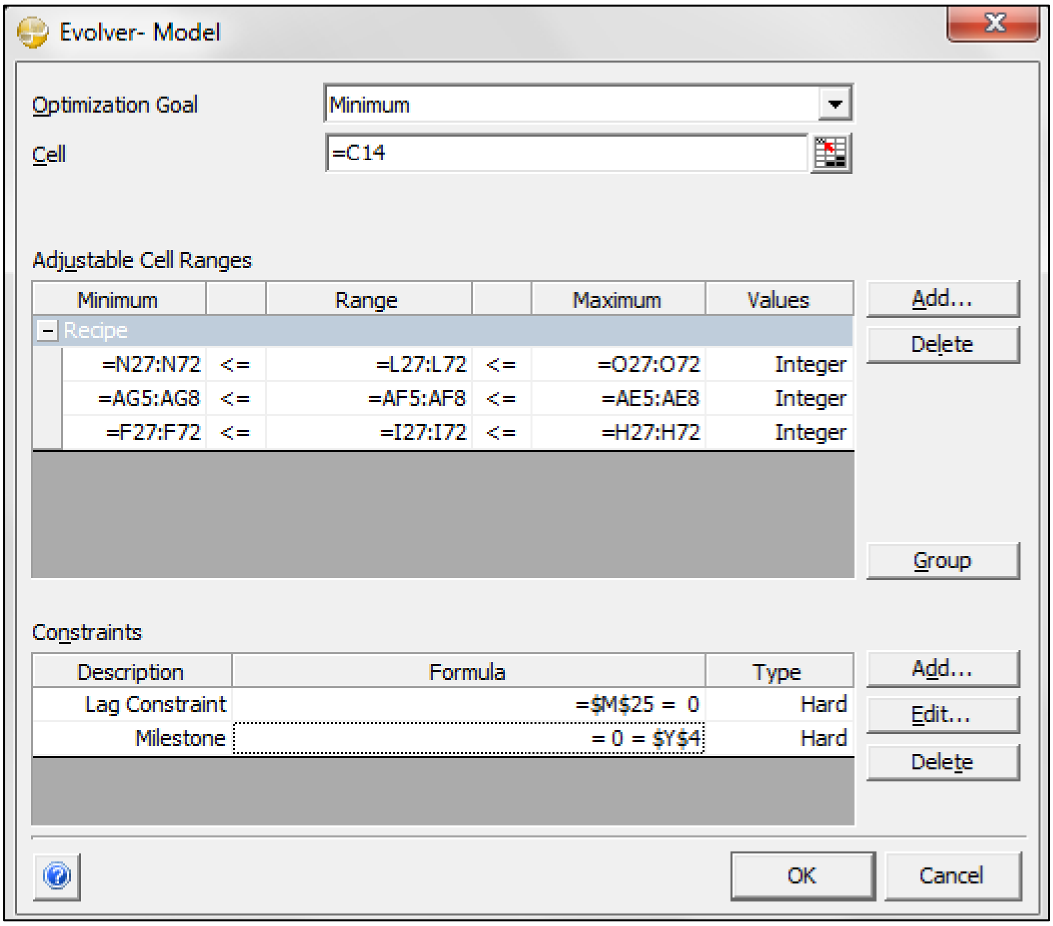

Figure 43: Evolver optimization settings

After defining all optimization settings, evolver is run to perform the optimization process. The set of variables are set to be the chromosomes, the group of variables forming one solution is called a population, while the fitness criteria is the optimization goal. Evolver starts in changing chromosomes for getting new populations of better fitness values (in this case, lower objective function value). At this stage, the genetic algorithms optimization is run by changing variables (chromosomes) and evaluating each of the developed combinations (measuring fitness of population). This process continues in changing variables and updating the fittest population so far. The optimization process depends mainly on the time it spends in changing variables and finding new near optimum results. This means that the more time the optimization process takes, the better results it can achieve. This optimization process was run for three hours to obtain the best possible results that could be achieved in this case.

5 . 2 . 5 Output module

Results obtained from this optimization process are presented in the output module. The output module presents the model results in table format and graphical representation. These include (1) the selected set of DLI alternatives as shown in Table 23, (2) the list of milestones defined for the program and a confirmation that all of them were achieved, as shown in Table 24, (3) a detailed final time schedule of the program, as shown in Table 25 and (4) a detailed monthly cash flow for the program, as shown in Table 26 and (5) a daily cash flow diagram for the program presenting its cash-in and cash-out requirements over the time span of the program, as shown in Figure 44.

Table 23: Final selected list of DLIs

#	Alternative	Total Amount	Distribution	Start Amount	Repetitive payment	Repetition duration	Activity 1	Activity1 Amount	Activity 2	Activity 2 Amount	Activity 3	Activity 3 Amount	Finish Amount
1.1	1	100,000,000	T & S	20,000,000			1.1.1.3	10,000,000	1.1.1.6	10,000,000	1.1.2.3	10,000,000	50,000,000
1.2	2	50,000,000	T & S	8,000,000			1.2.1.2	7,500,000	1.2.1.4	7,500,000			27,000,000
2.1	3	90,000,000	T & S	30,000,000			2.1.1.3	8,000,000	2.1.1.6	6,000,000	2.1.2.3	6,000,000	40,000,000
2.2	1	59,250,000	T & S	5,000,000			2.2.1.2	9,250,000	2.2.1.4	10,000,000			35,000,000

Table 24: Milestones achievement

	Description	Date	Related Item	Relation	Actual	Confirmation
M.1	Start Date	0	Start	Start	0	Achieved
M.2	Finish Date	2100	Finish	Finish	1984	Achieved
M.3	Project 1.1.2 Finish	1200	1.1.2	Finish	1034	Achieved
M.4	Project 1.2.1 Finish	1200	1.2.1	Finish	1034	Achieved

Table 25: Program time schedule

Activity	Type	Description	Start Date	Finish Date
1	R.A.	Result Area 1	7/2/18	4/30/21
1.1	DLI	DLI 1.1	7/2/18	4/30/21
1.1.1	Proj.	Project 1.1.1	7/2/18	10/17/19
1.1.1.1	Act.	Activity 1.1.1.1	7/2/18	8/30/18
1.1.1.2	Act.	Activity 1.1.1.2	8/31/18	9/24/18
1.1.1.3	Act.	Activity 1.1.1.3	8/31/18	11/2/18
1.1.1.4	Act.	Activity 1.1.1.4	11/3/18	2/13/19
1.1.1.5	Act.	Activity 1.1.1.5	2/14/19	8/15/19
1.1.1.6	Act.	Activity 1.1.1.6	8/16/19	10/17/19
1.1.2	Proj.	Project 1.1.2	11/13/19	4/30/21
1.1.2.1	Act.	Activity 1.1.2.1	11/13/19	1/28/20
1.1.2.2	Act.	Activity 1.1.2.2	2/13/20	5/19/20
1.1.2.3	Act.	Activity 1.1.2.3	3/18/20	5/16/20
1.1.2.4	Act.	Activity 1.1.2.4	6/13/20	12/15/20
1.1.2.5	Act.	Activity 1.1.2.5	6/20/20	1/5/21
1.1.2.6	Act.	Activity 1.1.2.6	1/21/21	4/30/21
1.2	DLI	DLI 1.2	10/18/19	4/30/21
1.2.1	Proj.	Project 1.2.1	10/18/19	4/30/21
1.2.1.1	Act.	Activity 1.2.1.1	10/18/19	1/22/20
1.2.1.2	Act.	Activity 1.2.1.2	1/23/20	5/28/20
1.2.1.3	Act.	Activity 1.2.1.3	5/29/20	9/11/20
1.2.1.4	Act.	Activity 1.2.1.4	9/12/20	1/25/21
1.2.1.5	Act.	Activity 1.2.1.5	1/26/21	4/30/21
2	R.A.	Result Area 2	5/1/21	12/6/23
2.1	DLI	DLI 2.1	5/1/21	12/6/23
2.1.1	Proj.	Project 2.1.1	5/1/21	6/27/22
2.1.1.1	Act.	Activity 2.1.1.1	5/1/21	6/28/21
2.1.1.2	Act.	Activity 2.1.1.2	6/29/21	12/26/21
2.1.1.3	Act.	Activity 2.1.1.3	6/29/21	9/1/21
2.1.1.4	Act.	Activity 2.1.1.4	12/27/21	4/30/22
2.1.1.5	Act.	Activity 2.1.1.5	9/2/21	4/3/22
2.1.1.6	Act.	Activity 2.1.1.6	5/1/22	6/27/22
2.1.2	Proj.	Project 2.1.2	6/28/22	12/6/23
2.1.2.1	Act.	Activity 2.1.2.1	6/28/22	9/9/22
2.1.2.2	Act.	Activity 2.1.2.2	9/10/22	1/6/23
2.1.2.3	Act.	Activity 2.1.2.3	1/7/23	3/13/23
2.1.2.4	Act.	Activity 2.1.2.4	3/14/23	6/6/23
2.1.2.5	Act.	Activity 2.1.2.5	6/7/23	10/15/23
2.1.2.6	Act.	Activity 2.1.2.6	10/16/23	12/6/23
2.2	DLI	DLI 2.2	9/17/21	1/11/23
2.2.1	Proj.	Project 2.2.1	9/17/21	1/11/23
2.2.1.1	Act.	Activity 2.2.1.1	9/17/21	12/16/21
2.2.1.2	Act.	Activity 2.2.1.2	1/22/22	5/27/22
2.2.1.3	Act.	Activity 2.2.1.3	4/19/22	8/20/22
2.2.1.4	Act.	Activity 2.2.1.4	6/12/22	10/21/22
2.2.1.5	Act.	Activity 2.2.1.5	10/29/22	1/11/23

Table 26: Program Monthly Balance

Date	Cash-In	Cumulative Cash-In	Cash-Out	Cumulative Cash-Out	Finance (Average)	Monthly Finance
07/2018	90,737,469	(90,737,469)	38,856,117	38,856,117	(51,881,352)	
08/2018		(90,737,469)		38,856,117	(51,881,352)	
09/2018		(90,737,469)		38,856,117	(51,881,352)	
10/2018		(90,737,469)		38,856,117	(51,881,352)	
11/2018		(90,737,469)		38,856,117	(51,881,352)	
12/2018		(90,737,469)		38,856,117	(51,881,352)	
01/2019	7,493,734	(98,231,203)	8,900,605	47,756,721	(50,474,482)	
02/2019		(98,231,203)		47,756,721	(50,474,482)	
03/2019		(98,231,203)	504,422	48,261,143	(49,970,060)	
04/2019		(98,231,203)		48,261,143	(49,970,060)	
05/2019		(98,231,203)		48,261,143	(49,970,060)	
06/2019		(98,231,203)		48,261,143	(49,970,060)	
07/2019		(98,231,203)	26,966,312	48,261,143	(49,970,060)	
08/2019		(98,231,203)	504,422	75,227,456	(23,003,747)	
09/2019		(98,231,203)		75,731,878	(22,499,325)	
10/2019	5,994,987	(98,231,203)	11,538,548	75,731,878	(22,499,325)	
11/2019		(104,226,190)	2,389,175	87,350,065	(16,876,125)	
12/2019	7,493,734	(104,226,190)	2,468,814	89,739,241	(14,486,950)	
01/2020		(111,719,925)	21,791,039	92,208,055	(19,511,870)	
02/2020		(111,719,925)	1,763,976	113,980,282	2,260,357	2,260,357
03/2020		(111,719,925)	2,356,330	116,214,958	4,495,034	2,234,677
04/2020		(111,719,925)	1,824,803	118,100,588	6,380,664	1,885,630
05/2020		(111,719,925)	1,921,782	119,925,391	8,205,467	1,824,803
06/2020		(111,719,925)	2,186,321	121,859,224	10,139,299	1,933,832
07/2020	13,114,035	(111,719,925)	19,236,928	124,045,545	12,325,620	2,186,321
08/2020		(124,833,960)	2,697,113	143,282,472	18,448,513	6,122,893
09/2020		(124,833,960)	1,913,256	145,979,586	21,145,626	2,697,113
10/2020		(124,833,960)	1,813,671	147,878,470	23,044,510	1,898,884
11/2020		(124,833,960)	1,755,165	149,692,141	24,858,181	1,813,671
12/2020		(124,833,960)	1,813,671	151,447,306	26,613,346	1,755,165
01/2021		(124,833,960)	10,076,419	153,260,977	28,427,017	1,813,671
02/2021		(124,833,960)	2,345,147	163,362,646	38,528,686	10,101,669
03/2021	5,620,301	(124,833,960)	3,034,328	165,707,793	40,873,834	2,345,147
04/2021		(130,454,261)	2,512,658	168,742,122	38,287,861	
05/2021	80,182,957	(152,935,464)	5,304,500	176,475,524	23,540,061	
06/2021		(210,637,218)	15,913,500	176,475,524	(34,161,694)	
07/2021		(210,637,218)		192,389,024	(18,248,194)	
08/2021		(210,637,218)		192,389,024	(18,248,194)	
09/2021	3,746,867	(210,637,218)	27,687,360	197,916,931	(12,720,287)	
10/2021	5,994,987	(214,384,085)	5,955,963	220,268,512	5,884,427	5,884,427
11/2021		(220,379,073)	5,763,835	226,224,475	5,845,402	
12/2021		(220,379,073)	13,842,180	231,988,309	11,609,237	5,763,835
01/2022		(220,379,073)	4,493,040	245,638,362	25,259,289	13,650,052

Date	Cash-In	Cumulative Cash-In	Cash-Out	Cumulative Cash-Out	Finance (Average)	Monthly Finance
02/2022		(220,379,073)	3,885,252	250,270,160	29,891,088	4,631,799
03/2022		(220,379,073)	4,500,581	254,155,412	33,776,339	3,885,252
04/2022		(220,379,073)	18,964,913	258,655,993	38,276,920	4,500,581
05/2022		(220,379,073)	12,488,309	283,190,288	62,811,216	24,534,296
06/2022		(220,379,073)	21,008,958	290,076,203	69,697,130	6,885,915
07/2022	6,931,704	(220,379,073)	10,019,796	311,302,633	90,923,560	21,226,430
08/2022	4,496,241	(227,310,777)	8,856,571	321,322,429	94,011,652	3,088,092
09/2022		(231,807,018)	5,802,794	330,073,252	98,266,235	4,254,583
10/2022		(231,807,018)	4,971,958	335,833,579	104,026,561	5,760,326
11/2022		(231,807,018)	7,672,376	340,886,279	109,079,261	5,052,700
12/2022	7,493,734	(231,807,018)	7,928,122	348,558,655	116,751,637	7,672,376
01/2023		(239,300,752)	5,845,515	356,486,777	117,186,025	434,388
02/2023	26,228,070	(239,300,752)	3,819,909	362,212,971	122,912,219	5,726,194
03/2023		(265,528,822)	3,766,451	366,032,880	100,504,058	
04/2023		(265,528,822)	3,177,907	369,768,836	104,240,014	3,735,956
05/2023	4,496,241	(265,528,822)	3,283,837	372,946,743	107,417,921	3,177,907
06/2023		(270,025,063)	2,285,182	376,230,581	106,205,518	
07/2023		(270,025,063)	2,130,734	378,478,566	108,453,503	2,247,985
08/2023		(270,025,063)	2,130,734	380,609,300	110,584,238	2,130,734
09/2023		(270,025,063)	2,136,938	382,740,035	112,714,972	2,130,734
10/2023		(270,025,063)	3,884,598	384,876,973	114,851,910	2,136,938
11/2023		(270,025,063)	5,350,496	388,871,187	118,846,125	3,994,215
12/2023		(270,025,063)	1,070,099	394,221,683	124,196,620	5,350,496
01/2024	29,974,937	(270,025,063)	4,668,676	395,113,432	125,088,370	891,749
02/2024		(300,000,000)		399,782,109	99,782,109	

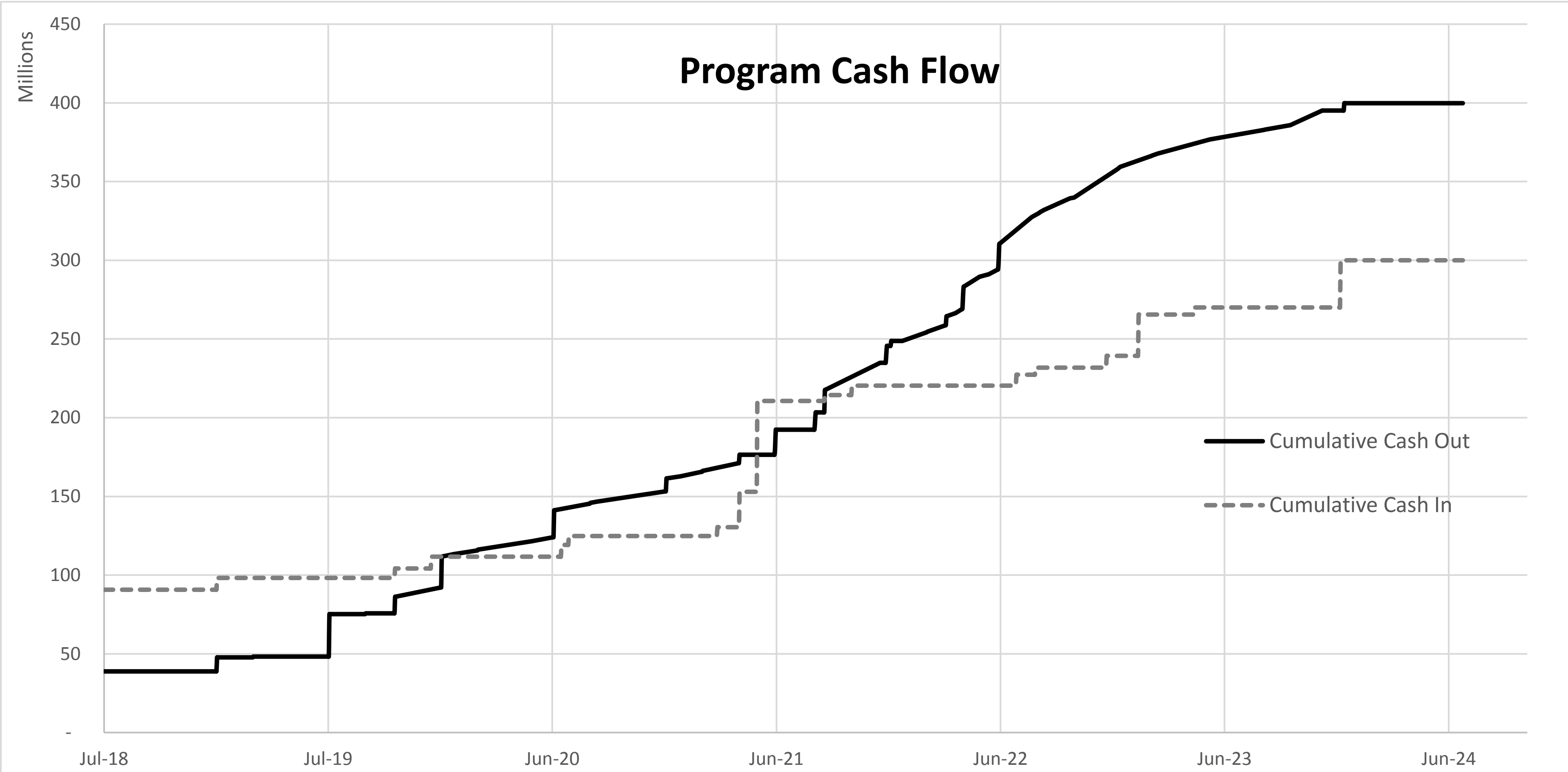

Figure 44: Program Cash Flow (S-curve)

5 . 3 Results and analysis

Through the optimization process, the model showed its capabilities in improving the program financial standing. It generated a decrease in the returned installment of 9.1%, a decrease in the average monthly spending on the program by 16% and a decrease in the maximum expenditure on the program by 8.17%. Figure 45 presents a comparison between the project cash flow before and after the application of the model on the program. Dashed lines represent the original cash-in (grey dashed curve) and cash-out (black dashed curve) curves of the program, while the straight lines represent the cash-in (grey solid curve) and cash-out (black solid curve) curves of the program after applying the model on them.

The model was capable of minimizing the gap between the cash-in and cash-out curves, leading to the decrease in government spending on the program, and it even led to a period of having an amount for cumulative cash in higher than cumulative cash out, as shown in year 2021 in the difference between both solid lines for cash-in and cash-out after applying optimization. This was achieved through minimizing the overall difference between cash-in and cash-out of the program, by changing alternatives of durations, DLI alternatives and adding lag durations.

Figure 46 presents a comparison between the net government financing profile over the life span of the program before and after applying the optimization process on the program. The model was capable of obtaining negative values for the cumulative finance for several months within year 2021. This was the main target from considering the minimization of the average monthly spending on the program in the optimization objectives. To obtain this result, the model made a different selection for the DLI alternative of DLI 2.1, where it selected an alternative with a higher advance payment.

The model selected alternative number 3, as shown in Table 23, which has 30 million advance payment instead of alternative one, which was initially selected, that has only ten million advance payment. This amount covered the cumulative cash out amount nearly for half the year of 2021.

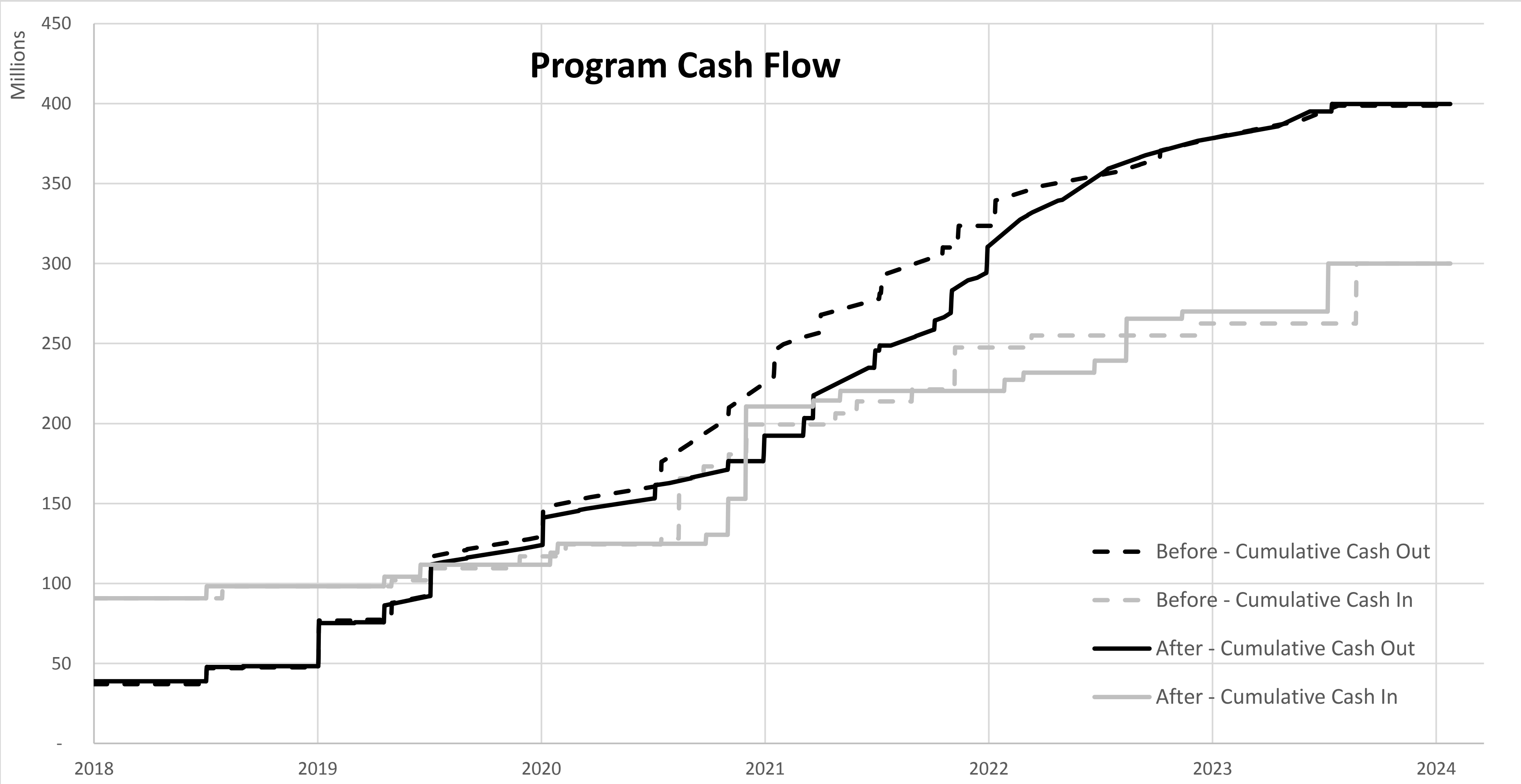

Figure 45: Program Cash flow comparison

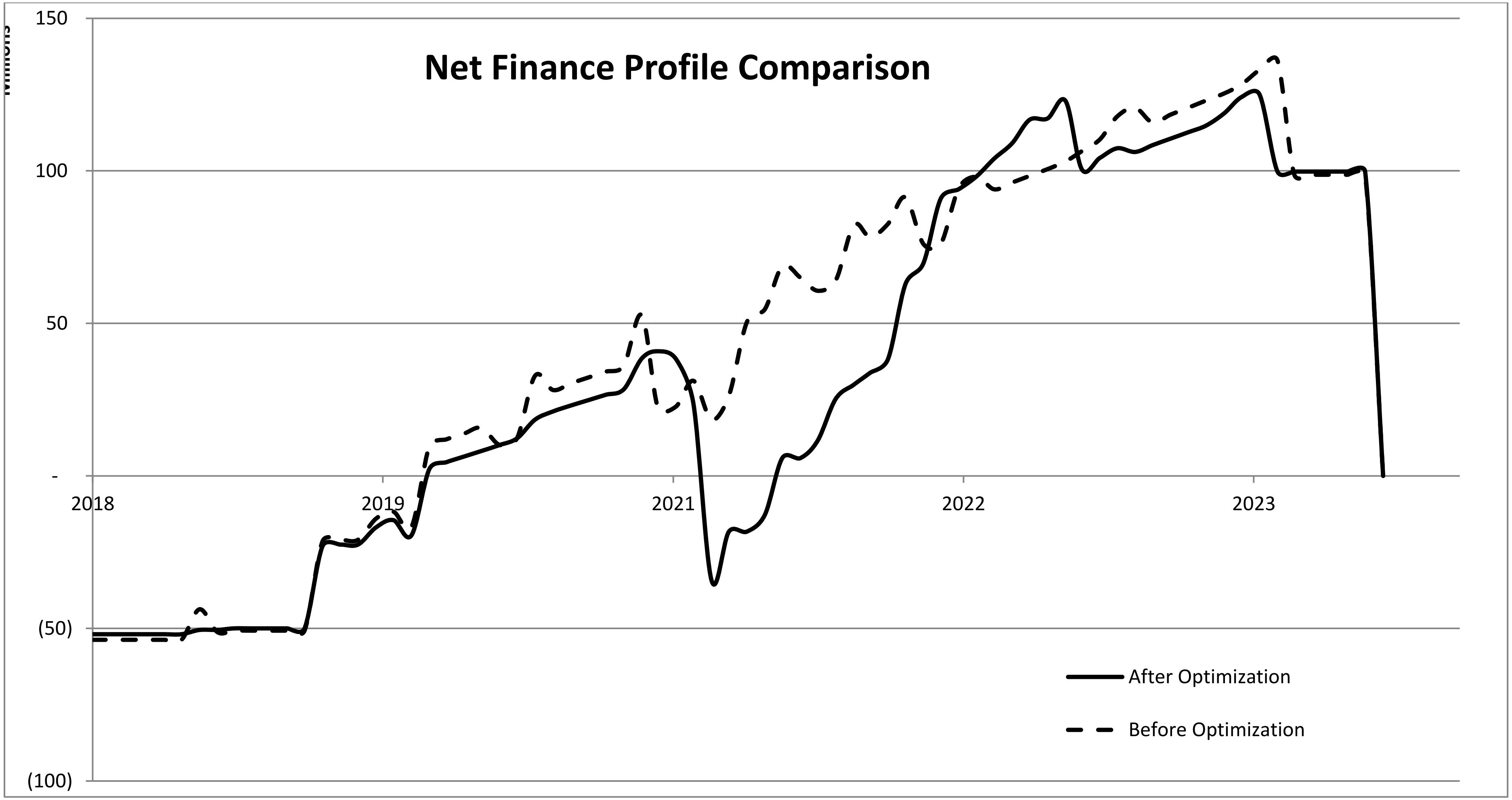

Figure 46: Net finance profile comparison

5 . 4 Summary

In this chapter, a case study is utilized to verify the capability of the developed model to obtain acceptable results and demonstrate its features. The program introduced consisted of four different DLIs. Each DLI included one or two projects. Each project included five or six activities. The range of alternatives were defined, and all stages for model application were demonstrated. After running the model optimization, it was observed that it was capable of obtaining optimized results with respect to (1) the decrease of maximum spending of the government on the program, (2) the decrease of the amount of loan installments and (3) the decrease of average monthly spending of the government on the program. The obtained results were manually reviewed, recalculated and found to be acceptable/applicable.

CHAPTER 6: VALIDATION

To validate the developed model, it was applied on one of the P4R operations currently being implemented that is the Sustainable Rural Sanitation Services Program-For-Results in Egypt (The World Bank, 2015-B). The government of Egypt received an approval for a total of USD 550 Million towards the program. This program has a PDO of “strengthening institutions and policies for increasing access and improving rural sanitation services in the governorates of Beheira, Dakahiya and Sharkiya in Egypt”.

6 . 1 Program Description

This program achieves such objective through three different result areas, each result area is broken down into different DLIs that represent its aim:

1. Result area 1: “Improved sanitation access”: this result area includes projects connecting the target villages with the national networks of Water supply and sanitation services

   1.1. DLI 1: At least 167,000 new household connections (about 1 million people) are connected to working sanitation systems in villages and satellites of the target areas. This is an output DLI. This means that people are having fully operational sanitation networks in compliance with agreed-upon standards.

   1.2. DLI 2: the transfer of Performance Based Capital Grants (PBCGs) by the Ministry of Housing, Utilities and Urban Communities (MHUUC) to the eligible Water and Sanitation Companies (WSCs). This is an action DLI. These grants are considered incentives for WSCs to ensure the achievement of an improvement in their performance.

2. Result area 2: “Improved operational systems and practices of Water and Sanitation Companies (WSC)”: this area includes the improvement process of the companies responsible for the Water supply and sanitation within the target governorates. This ensures that the projects executed within the first result area are sustained through well established companies with adequate capacity and improved operations for operating and maintaining such projects. It is considered an indirect result area where it serves the original PDO through supporting the companies responsible for sustaining the program projects.

   1.3. DLI 3: the design and implementation of an Annual Performance Assessment (APA) for the evaluation of the performance of the WSCs. This is a system action DLI. This assessment ensures that the WSCs consistently achieve an overall improved financial and technical performance in managing the executed projects.

3. Result area 3: “Strengthened national sector framework”: this result area ensures that the outputs of both previous results areas are sustained through an enabling environment supported by the government within Egypt. For example, changing the national tariff structure would ensure that the water supply networks are going to be consistently financed in the future. This is considered an indirect result area

   1.4. DLI 4: An introduction of a new structure for the national tariff. This is an action DLI. This indicator ensures the financial sustainability of the executed projects and the ability of the government to finance the operation and maintenance processes of such projects.

1.5. DLI 5: The establishment of a Project Management Unit (PMU) and the introduction of a National Rural Sanitation Strategy by the MHUUC. This is an action DLI. This DLI ensures that the main goals of this program continue to be applied on the other governorates within the country and that a strategy/plan is already existing. It also ensures that the tools required for this application are present within the country and can be easily applied through the financial resources made available through the financial resources available from this program.

1.6. DLI 6: the presentation and agreement of a Standard Procedures for Land Acquisition. This is an action DLI. This DLI ensures that any lands required for the execution of the program are obtained easily. It also ensures that the already available processes are simplified. This DLI will ensure that the already available land acquisition procedures do not delay any of the activities falling under DLI 1.

The main bulk of the program financing (40%) is directed towards DLI 1, for financing three WSCs to finalize their planned investments for rural sanitation infrastructure, within result area 1. 31% is allocated for strengthening the WSCs and improving their capacity. The remainder of financing is allocated for strengthening the national framework supporting the implementation of the program and ensuring its sustainability. The main concept applied in this program follows the track of the P4R mechanism, which supports the main target of a program while financing other activities that ensure its success and enforce its sustainability.

Based on the DLIs structure, 40% of the allocated amounts for this program is set to be received by the Egyptian government from the WB while nearly 90% of the government spending is on projects required for achieving this DLI. This means that the government has to efficiently manage the time schedule of the achievement of other program DLIs for being able to finance the program through program support and not through the country's general budget.

6 . 2 Program Flow of Funds

Figure 47 describes the flow of funds starting from disbursements made by the WB to the payment of progress invoices to implementing contractors. This process starts after an agreement is reached between the WB and the government. The financial relation between the WB and the government is managed by the Ministry of Finance (MoF) as it is responsible for the management of all financial supports received from lending institutions. The relation between the WB and the MoF is two-way as the WB provides financial support/Funds to the MoF, while the MoF is responsible for financial reporting and the follow-up of financial audits made by the WB on the program. Received funds are then made available for the MHUUC/Project Management Unit responsible for managing the program. The PMU has several responsibilities including (1) technical reporting to the WB, about the status of the program and receiving technical support from the bank, (2) financial reporting to the MoF for making arrangements for required disbursements with the WB and (3) the management of transferred funds to governmental implementing agencies (WSCs). In this case, the transfer of funds from the government to WSCs is made through semi-annual budget transfers. Implementing agencies use the received funds for satisfying the financial requirements of the program, represented in the payment of invoices for implementing contractors/subcontractors.

6 . 3 Cash Flow Optimization

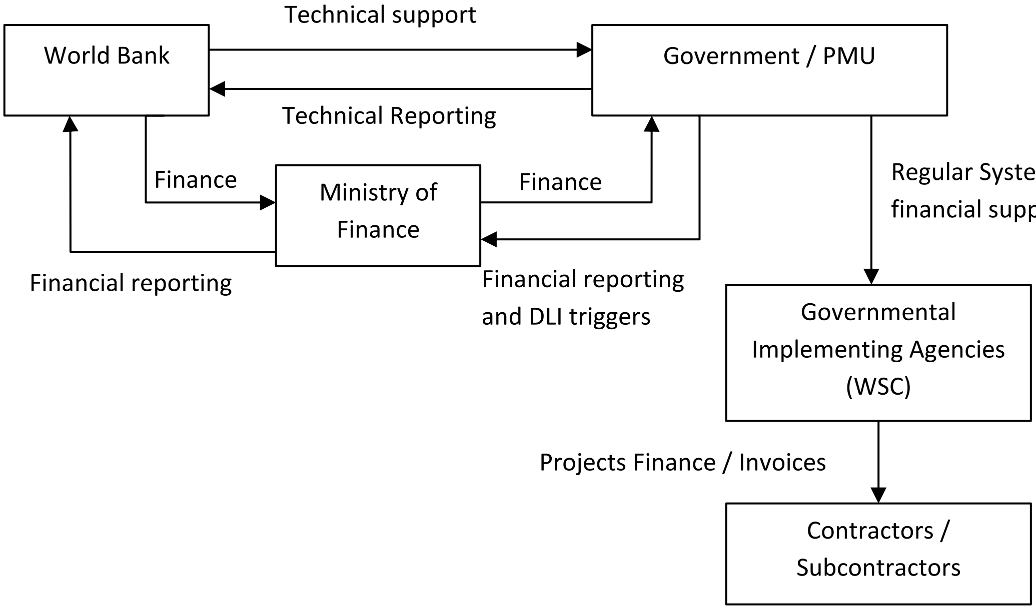

Figure 47: SRSSP Financing Transfers

General financing data of the model was obtained from the Program Appraisal Document (PAD) (The World Bank, 2015-A). This PAD included all data relevant to financial transfers between the WB and the government.

6 . 3 . 1 Program Inputs

Figure 48 shows the loan financial conditions and Figure 49 shows the program initial data, obtained from the PAD. This model had three different responsible agencies other than the Project Management Unit (PMU), that are responsible for technically and financially managing the program. These agencies are the three water and sanitation companies (WSC) of Sharkeya, Dakahleya and Beheira Governorates. These three WSCs are responsible for the management of projects within their governorates. This means that every six months the PMU has to schedule a financial transfer to each WSC for financing activities/invoices within its projects. The model simulates both financial transfers, (1) between the government/PMU and the WSC and (2) between the WSCs and the implementation contractors.

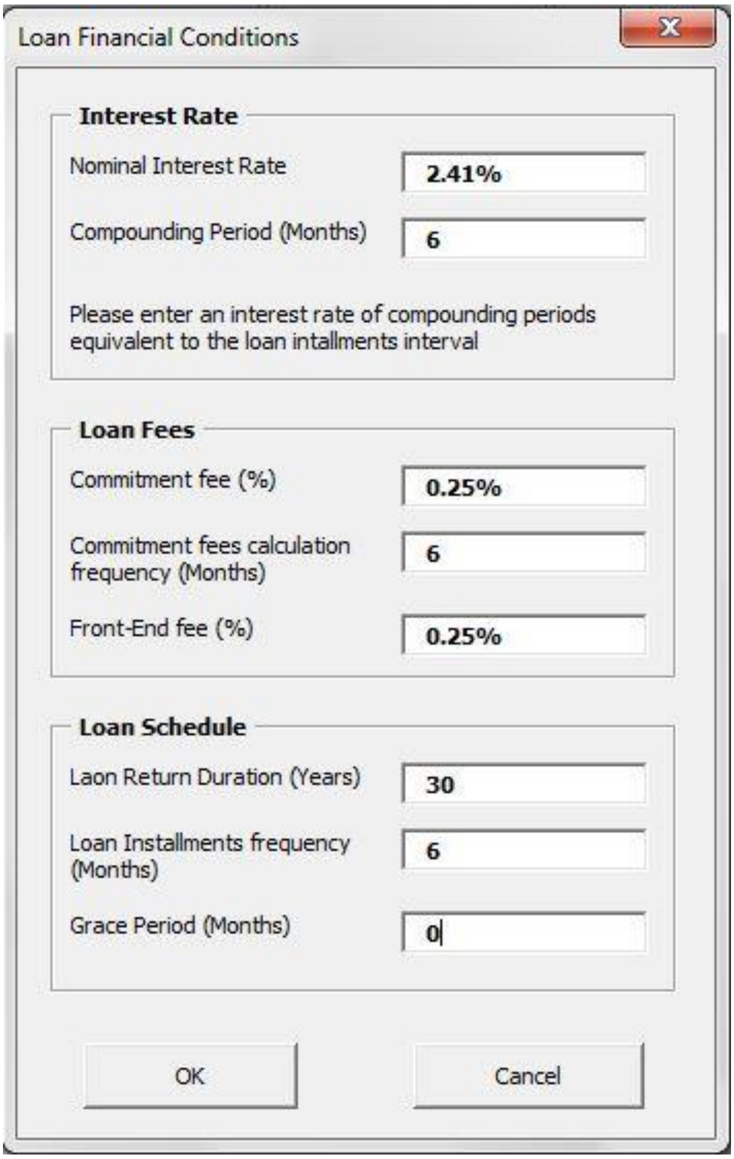

Figure 48: SRSSP Loan Financial Conditions

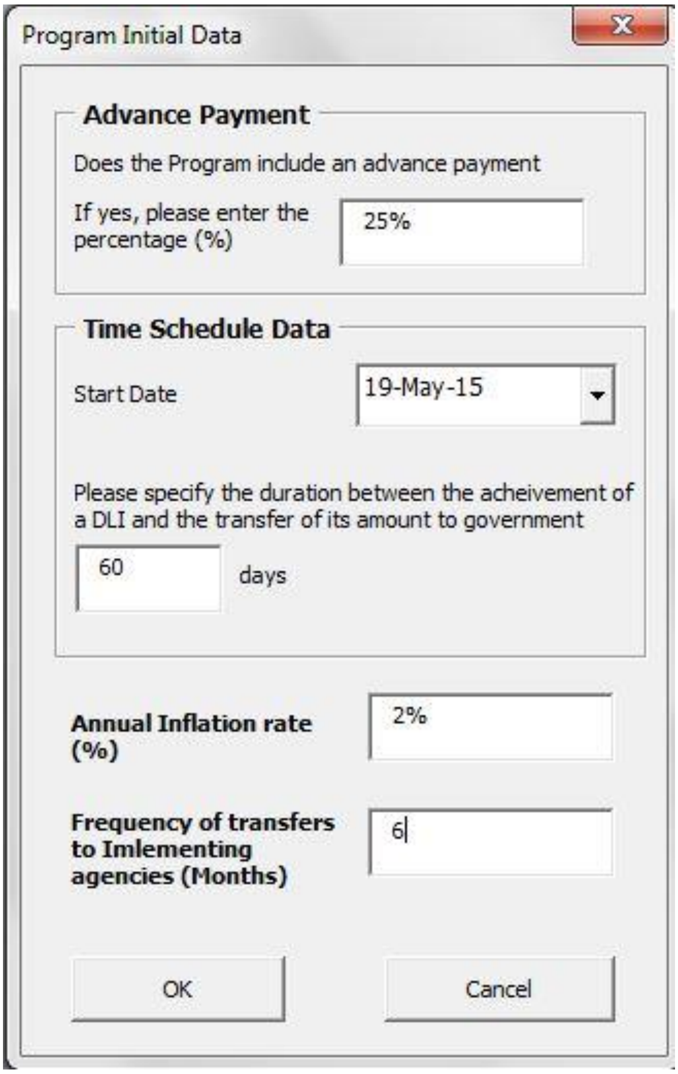

Figure 49: SRSSP Program Initial Data

Responsibilities defined in this program were the (1) Project Management Unit (PMU) within the Ministry of Housing, Utilities & Urban Communities (MHUUC), (2) Sharkia Water Sanitation Company, (3) Dakahleya Water Sanitation Company and (4) Beheira Water Sanitation Company. The PMU is responsible for the overall management of the program, coordinating financial transfers with the Ministry of Finance (MoF) and technical coordination with the WB. Each water sanitation company is responsible for the management of the implementing agencies, such as contractors and designers of projects, according to the plan agreed with the PMU.

Result areas and DLIs were inserted as described in section 6 . 1 , each DLI was inserted under its relevant result area. In this case, no alternatives were added for DLIs as the program is currently in pipeline and all DLIs were already settled with the WB. This led to ignoring DLI alternatives option from the optimization process. The main time schedule for this program was obtained from the program implementation agency. DLI details, projects, activities and milestones details from this plan were added in the model. Results obtained from this plan are called the “before optimization results”.

The main bulk of activities were concentrated under DLI#1, which is the execution of new operating household connections. This means that for each household connection the WSC has to manage two types of projects, which are the pipeline connections to be made for houses and the construction of the Waste Water Treatment (WWT) facilities. So, a household connection is considered operating only if its WWT facility and household connections are finished and operating. This means that the Egyptian government receives the amount agreed for each household connection only at this point.

Activities under each project were added, according to the received schedule. Relationships between activities were added according to the planning logic in this schedule. Finally, milestones were added according to the agreed milestones in the PAD document.

6 . 3 . 2 Program Optimization

Cash flow optimization was performed on this program, while considering the objective function of decreasing both the maximum required financing and the returned installments. A new time schedule and detailed cash flow was obtained for the program.

This schedule does not consider any financing amounts set or the plan originally made by the Egyptian government.

It was observed that the model worked on normalizing the semi-annual transfers made to WSCs. This was achieved through spreading projects of each WSC over the lifetime of the program, instead of planning them concurrently. It also worked on rescheduling activities that trigger DLI transfers in dates having higher amounts required for finance by the government. This would decrease the overall spending of the government on the program. It also considered balancing financial requirements of each WSC for managing implementation contractors with the overall financial stability of the program from the PMU's point of view.

As shown in Figure 48 & Figure 49, the interest rate is higher than the sum of both the commitment fee and the inflation rate. This means that the model may be in favor of delaying projects than making them start earlier. This is translated into a lower interest amount, for a slightly higher commitment fee and an increased cost of the projects, caused by inflation.

6 . 4 Outputs & analysis

After running the optimization process, the model showed a decrease in the returned installment of nearly 12.5% and it also decreased the maximum expenditure on the program by nearly 10%.

6 . 4 . 1 Cash-Flow Analysis

Figure 50 shows a comparison between the cumulative cash flows of the program before and after applying optimization. The decrease in expenditure is shown in the difference between the length of both the vertical dotted line in year 2019 (representing the maximum amount of finance required after applying optimization on the program) and the vertical thick straight line in year 2020 (representing the maximum amount of finance required in the original plan of the government). It shows that the optimization process worked more on spreading projects over the lifetime of the program, for reducing the continuously required finance for the program. This also led to the delay of amounts received from the WB from the first half of the program lifetime to its second half, this is shown in the difference between the positions of Cash-out curve in year 2018 and year 2020.

It is observed from the cash-out curves of government in both cases, that each year there are two high steps that occur at the middle and end of year, these two steps represent the transfers made from the government to the WSCs, while steps in the cash-in curves represent amounts received from the WB when achieving DLIs.

The difference between curves of cash-in and cash-out in both cases at the end of the program (year 2021) is not significant, while there is a nearly 14.5% saving in the overall returned installment, this is shown in the balance made by the model in stabilizing the schedule to absorb any fees, interests or inflation for serving the goal of decreasing the returned loan amount. This was achieved through spreading program activities/projects all-over the program lifecycle, while considering their effect on the returned loan amount.

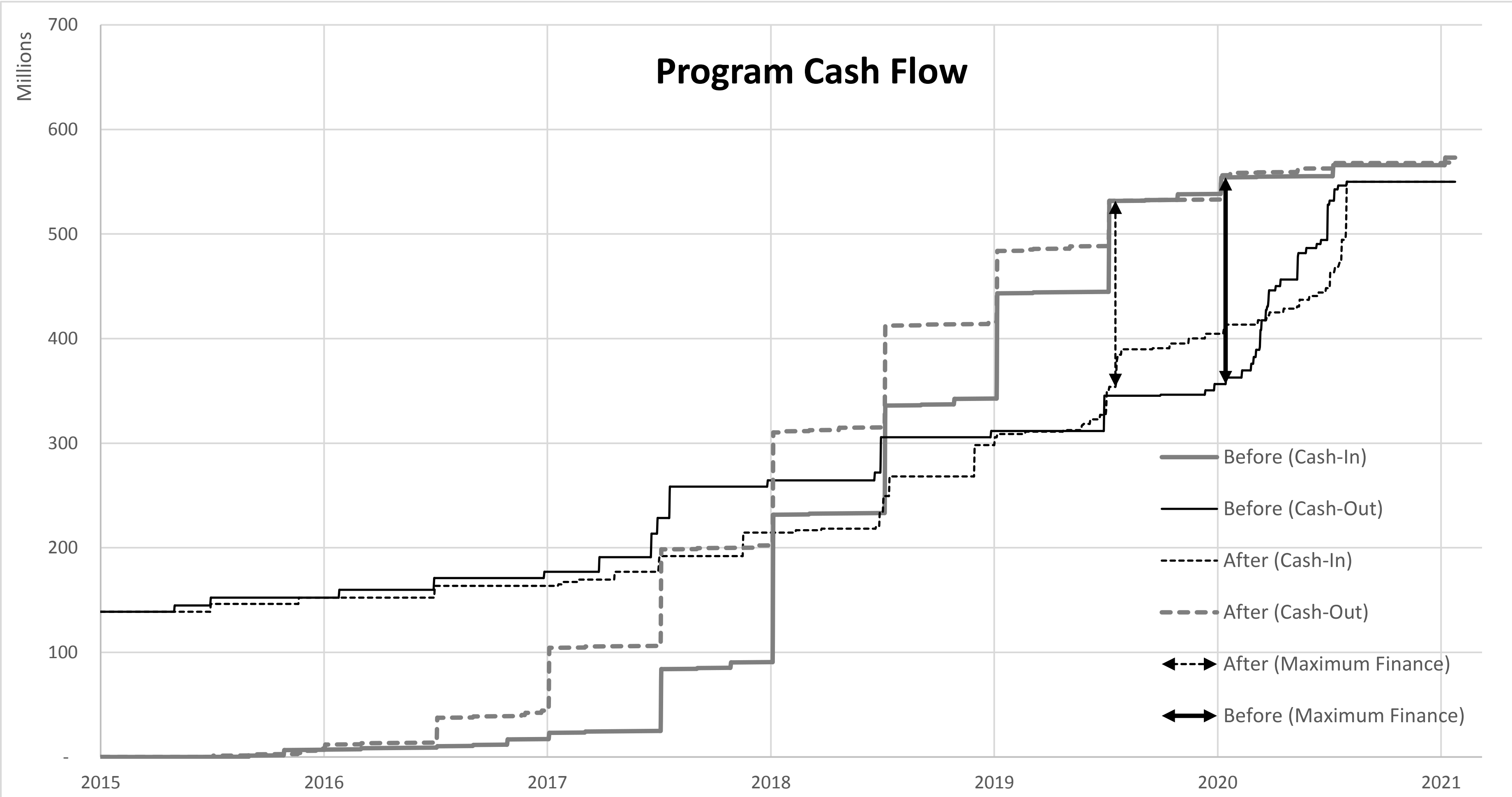

Figure 50: Program Cumulative Cash Flow Diagrams Comparison

6 . 4 . 2 Expenditure Analysis

When analyzing the spending profile of the government on the program, it was found that the model decreased the overall spending of the government on the program by 10% but it increased the duration of this spending. This can be evident in the difference between the two curves shown in Figure 51, where the solid curve represents the spending profile of the government on the program before applying optimization while the dotted line represents the government spending after applying optimization. So the peak that took place in year 2020 (highest point in the dotted curve) before applying optimization was reduced to the peak in the solid line in the middle of year 2019 (highest point in the solid curve).

It was noticed that for achieving this decrease of 10% in the maximum spending on the program, the model increased the duration where the government has amounts on account of the program. This means that the government has to select among increasing the duration of supporting the program and the decrease in the overall support offered for this program. For overcoming this effect of the optimization process, the average monthly expense on the program was included in the optimization process. This was done through changing the objective function to become the multiplication of the loan installment amount, maximum spending and the average monthly support of government on program. After performing the optimization process, the model reduced the loan installment amount by 13.5%, the average monthly spending by 11.6% while it only reduced the maximum spending on the program by nearly 3%. This means that the government will have to make the trade-off between the duration it supports the program and the maximum amount of spending on it.

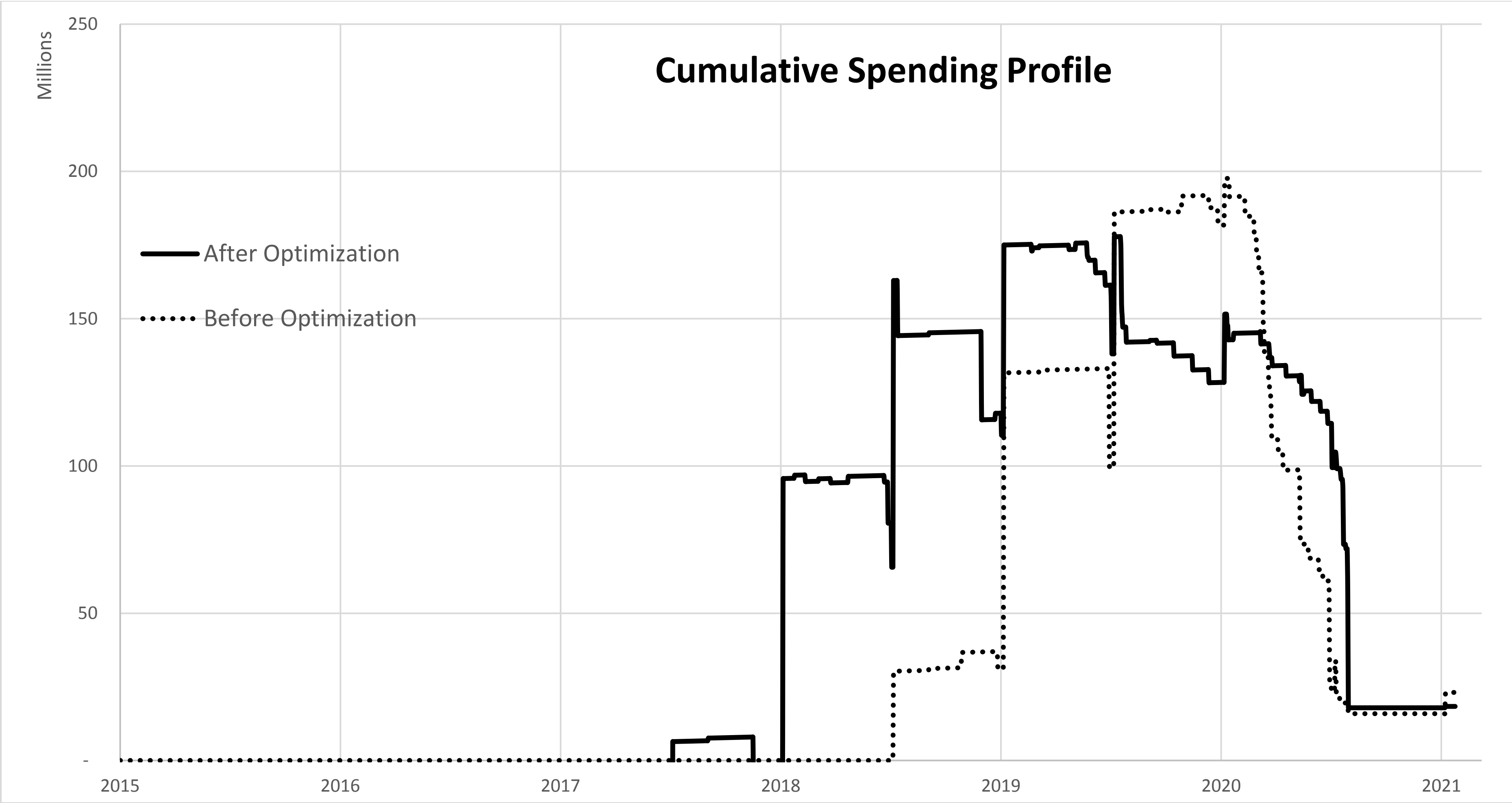

Figure 51: SRSSP Cumulative Government Spending Profile

6 . 5 Summary

In this chapter, the developed model was applied on the Sustainable Rural Sanitation Services Program in Egypt. Program details were described in detail in the beginning of this chapter and how funds received from the WB are handled until they are received by the implementing agencies. Steps of entering program inputs in the model were presented. These include general data about the program, data about the WB financial conditions and fees, scheduling and cost data about the program contents. Program details were obtained from the program implementing agency. The model showed its capability of reducing the overall government spending on the program and the amount of loan installment returned at the end of the program, while balancing the average spending on program.

CHAPTER 7: CONCLUSION AND FUTURE RESEARCH

Development lending agencies are currently shifting towards results-based funding mechanisms, for their wide variety of benefits, shown in the shift of risks to the borrowing entity/country and improved utilization of the lent amounts. The management of infrastructure programs financed through results-based finance mechanisms requires an integration of multiple projects management techniques and financing requirements of these mechanisms. The main feature of RBF mechanisms is that they link disbursements to the achievement of results. This requires the borrowing country to pre-finance program contents, which forms cash flow gaps. Managing this type of programs also requires the application of multiple projects management techniques.

According to research, the failure to plan financing requirements for projects efficiently is considered one of the main reasons for business failure. This also applies to projects run by the governments, where strategic priorities control the direction of financing provided by the government.

7 . 1 Research Summary

The main aim of this research is to provide guidance for borrowing countries in applying RBF mechanism. This aim is achieved through the development of a Decision Support System that supports governments in decision making throughout all stages of RBF starting from initiation to closing. The Program-For-Results mechanism offered by the World Bank is used as an example of the RBF mechanisms for verification. This DSS follows the stages of P4R application as defined by the WB but from the government point of view. The DSS is developed using Microsoft Excel as a spreadsheet modeling tool, Visual Basic Applications (VBA) as a programming tool for guiding users throughout the DSS, and Evolver Add-In to excel for applying Genetic Algorithms for optimization. The model focuses on the borrower preparation phase which offers the full flexibility for the government to use all features of the model optimization, and then uses these processes as the main building block of the model for being updated in later stages. The model helps the user ensure that the program is eligible for P4R support and then guides the user through the program assessments required by the WB. The scheduling and cost optimization section of the model provides the user, at each stage, (1) an original time schedule, (2) an optimized time schedule, (3) an original cash flow and cash flow analysis and (4) an optimized cash flow and its relevant cash flow analysis. The model was verified using a case study to ensure it provides valid results, it was also validated through the application on the Sustainable Rural Sanitation Services program in Egypt.

The developed DSS model used P4R as a sample for RBF mechanisms offered by international financial institutions; however, tools and techniques applied within this model are applicable to any other RBF mechanism offered by other institutions. These techniques are the main driving concepts of RBF, where the model starts by the proposal of a program by the borrowing government, then several rounds of negotiation between the borrowing government and the bank. Then the application of the program and the achievement of results, and their verification by a third-party, going through a cycle of approvals and verification. Finally the closing stage and learning from lessons within the program.

7 . 2 Future Research

This model focuses on supporting governments in the planning and execution phases of programs supported by the P4R mechanism, further research could be performed in the below areas:

1. The model can be enhanced to allow for supporting governments dealing with multiple projects while using other funding mechanisms

2. The model can consider available resources within the country for implementing the program. This could be represented in the number of contractors available in the country for executing this type of programs, which could be a constraint on the reliability of the developed schedule.

3. The model can integrate other borrowing mechanisms for the remaining amounts that have to be financed by the government, so the overall spending of the government during the program implementation period is negligible and is all converted to installments paid following the program closing, or considered through the planning process to expect any needs for further financial support and their timing

4. The developed model can be integrated with other scheduling programs that would enable it to have better scheduling capabilities

5. The model can enable the user to add preferences for projects in starting earlier or later, and not to only abide by the financial optimization results

6. The model can be expanded to include other financial institutions (other than the WB) for the user to select the most appropriate mechanism.

CHAPTER 8: BIBLIOGRAPHY

Abido, M. & Elazouni, A., 2010. *Multiobjective evolutionary finance-based scheduling: the entire projects' portfolio.* Proceedings of the International Conference on Computing in Civil and Building Engineering.

Abido, M. & Elazouni, A., 2011. Multiobjective evolutionary finance-based scheduling: entire projects' portfolio. *Journal of Computing in Civil Engineering,* 25(1), pp. 85-97.

ADB, 2015. *The Asian Development Bank.* [Online], Available at: www.adb.org, [Accessed December 2015].

ADB, 2019. *Results-ased Lending projects.* [Online], Available at: https://www.adb.org/site/public-sector-financing/results-based-lending-programs/projects, [Accessed July 2019].

AFDB, 2015. *African Development Bank Group.* [Online], Available at: www.afdb.org, [Accessed December 2015].

AFDB, 2017. *Bank Group Policy on Results-Based Financing,* African Development Bank Group.

Afruzi, E. N., Najafi, A. A., Roghanian, E. & Mazinani, M., 2014. A Multi-Objective Imperialist Competitive Algorithm for solving discrete time, cost and quality trade-off problems with mode-identity and resource-constrained situations. *Computers & Operations Research,* Volume 50, pp. 80-96.

Afshar, A., Ziaraty, A., Kaveh, A. & Sgarifi, F., 2009. Non-dominated archiving multicolony ant algorithm in time-cost trade-off optimization. *Journal of Construction Engineering and Management,* 135(7), pp. 668-674.

Ahuja, H. N., 1976. *Construction performance Control by Networks.* New York: Wiley.

Al-Shihabi, S. T. & AlDurgam, M. M., 2017. A max-min ant system for the finance-based scheduling problem. *Computers and Industrial Engineering,* Volume 110, pp. 264-276.

Ammar, M. A., 2011. Optimization of Project Time-cost trade-off problem with discounted cash flows. *Journal of Construction Engineering and management,* Volume 1, pp. 65-71.

Antill, J. & Woodhead, R., 1982. *Critical path Methods in Construction Practices.* 3rd Edition ed. New York: Wiley.

Arditi, D., Koksal, A. & Kale, S., 2000. Business failures in the construction industry. *Engineering, Construction and Architectural Management,* 7(2), pp. 120-132.

Bahrgava, V. I. N. A. Y., 2006. The role of the international financial institutions in addressing global issues. *The World Bank,* pp. 393-410.

Bakker, A., 1996. *International Financial Institutions.* Pearson Education Limited.

Chan, W., Chua, D. & Kannan, G., 1996. Construction resource scheduling with genetic algorithms. *Journal of Construction engineering and Management,* 122(2), pp. 125-132.

Chen, P., Batson, R. & Dang, Y., 2010. *Applied Integer Programming: Modeling and Solution.* New York: John Wiley and Sons.

Cooper, R. G., Edgett, S. J. & Kleinschmidt, E. J., 2000. New Problems, New Solutions: Making Portfolio Management More Effective. *Research Technology Management,* 43(2), pp. 18-33.

Dasgupta, S., Papadimitriou, C. & Vazirani, U., 2006. *Algorithms.* New York: McGraw-Hill.

D, C., 1985. *Construction Management Planning and Finance.* London: Construction press.

Dooley, L., 2000. *Systems Innovation Management.* National University of Ireland, Galway.

Dooley, L., Lupton, G. & O'Sullivan, D., 2005. Multiple project management: a modern competitive necessity. *Journal of Manufacture Technology Management,* 16(5), pp. 466-482.

Dooley, L. & O'Sullivan, D., 2003. Developing a software infrastructure to support systemic innovation through effective management. *The International journal of Technological Innovation and Entrepreneurship (Technovation),* 23(8), pp. 689-704.

Eberhart, R. & Shi, Y., 1998. *Comparison between genetic algorithms and particle swarm optimization.* San Diego, California, USA, Proceedings of the 7th International Conference on Evolutionary Programming VII, pp. 611-616.

EBRD, 2015. *The European Bank for Reconstruction and Development.* [Online], Available at: www.ebrd.com, [Accessed December 2015].

El-Abbasy, M. S., Elazouni, A. & Zayed, T., 2016. MOSCOPEA: Multi-Objective construction scheduling optimization using elitist non-dominated sorting genetic algorithms. *Automation in Construction,* Volume 71, pp. 153-170.

El-Abbasy, M. S., Elazouni, A. & Zayed, T., 2017. Generic Scheduling Oprimization Model for Multiple Construction projects. *Journal of Computing in Civil Engineering,* 31(4), p. 04017003.

El-Abbasy, M. S. K., 2015. *Multi-Objective Multi-Project Construction Scheduling Optimization.* Concordia University.

Elazouni, A., 2009. Heuristic method for multi-project finance-based scheduling. *Construction Management and Economics*, 27(2), pp. 199-211.

Elazouni, A. & Abido, M. A., 2014. Enhanced Trade-off of Construction projects: Finance-Resource-Profit. *Journal of Construction Engineering and Management,* 140(9), p. 04014043.

Elazouni, A. & Gaballah, A., 2004. Finance-based scheduling of construction projects using integer programming. *Journal of Construction Engineering and Management*, 130(1), pp. 15-24.

Elazouni, A. & Metwally, F., 2005. Finance-based scheduling: tool to maximize project profit using improved genetic algorithms. *Journal of Construction Engineering and Management,* 131(4), pp. 400-412.

Elazouni, A. M. & Metwally, F. G., 2007. Expanding Finance-Based Scheduling to Devise Overall-Optimized Project Schedules. *Journal of Construction Engineering and Management,* 133(1), pp. 86-90.

Eldridge, M. & Tekolste, R., 2016. *Results-Based financing approaches,*

Elonen, S. & Artto, K. A., 2003. Problems in managing internal development projects in multi-project environment. *International Journal of Project Management,* 21(6), pp. 395-402.

El-Rayes, K. & Kandil, A., 2005. Time-cost-quality tradeoff analysis for highway construction. *ASCE Journal of Construction Engineering and Management,* 131(4), pp. 477-486.

Engwall, M. & Jerbrant, A., 2003. The resoirce allocation syndrome: the prime challenge of multi-project management. *International Journal of Project Management*, 21(6), pp. 403-409.

European Investment Bank, 2015. *European Investment Bank.* [Online], Available at: www.eib.org, [Accessed December 2015].

Ezeldin, A. & Moussa, M., 2017. *Framework for Selection of International Financing Instruments for Infrastructure Projects.* Vancouver, Canada, , pp. CON-020:1-10.

Ezeldin, A. & Zahran, K., 2017-A. *Process Optimization of Program-For-Results Funding Mechanism for Infrastructure Programs.* New York, USA, International Conference on Sustainable Infrastructure, American Society of Civil Engineers Conference.

Fathi, H. & Afshar, A., 2010. GA-based Multi-Objective Optimization of finance based construction project scheduling.. *KSCE Journal of Civil Engineering,* 14(5), pp. 627-638.

Fayad, A., Hosny, O., Elhakeem, A. & Zahran, K., 2012. Continuous rescheduling optimization approach for successful real estate projects. *Engineering Project Organization Journal,* 3(3), pp. 168-183 (16).

Feng, C., Liu, L. & Burns, S., 1997. Using Genetic Algorithms to solve construction time-cost trade-off problems. *ASCE Journal of Construction Engineering and Management,* 123(3), pp. 184-189.

Ferns, D. C., 1991. Developments in Programme Management. *International Journal of Project Management,* 9(3), pp. 148-156.

Fondahl, J., 1961. *A non-computer approach to the critical path method for the construction industry,* Stanford, CA: Stanford University.

Gajpal, Y. & Elazouni, A., 2015. Enhanced heuristic for finance-based scheduling of construction projects. *Construction Management and Economics,* 33(7), pp. 531-553.

Gelb, A., Diofasi, A. & Postel, H., 2016. *Program for Results: The First 35 Operations,*

Gelb, A. & Hashmi, N., 2014. *The Anatomy of Program-For-Results: An Approach to Results-based Aid,*

Guo, H., Zhu, K., Ding, C. & Li, L., 2010. Intelligent optimization for project scheduling of the first mining face in coal mining. *Expert Systems with Applications,* 37(2), pp. 1294-1303.

Hegazy, T., 1999-a. Optimization of Construction Time-Cost Trade-off Analysis Using Genetic Algorithms. *Canadian Journal of Civil Engineering,* 26(6), pp. 685-697.

Hegazy, T., 1999-b. Optimization of Resource Allocation and Leveling Using Genetic Algorithms. *Journal of Construction Engineering and Management,* 125(3), pp. 167-175.

Hegazy, T., Shabeeb, A., Elbeltagi, E. & Cheema, T., 2000. Algorithm for scheduling with multiskilled construction resources. *ASCE Journal of COnstruction and Management,* 126(6), pp. 414-421.

IIB, 2015. *The International Investment Bank.* [Online], Available at: www.iib.int, [Accessed December 2015].

International Finance Corporation, 2015. *IFC - World Bank Group.* [Online], Available at: http://www.ifc.org/, [Accessed December 2015].

IsDB, 2015. *The Islamic Development Bank.* [Online], Available at: www.isdb.org, [Accessed December 2015].

JICA, 2015. *The Japanese International Cooperation Agency.* [Online], Available at: www.jica.go.jp, [Accessed December 2015].

Kantorovich, L., 1940. *A new method of solving some classes of external problems.* USSR, , pp. 211-214.

Katz, R. L., 1976. Skills of an effective administrator. *Harvard Business Review,* 33(1), pp. 33-42.

Kelley, J., 1961. Critical-path planning and scheduling: Mathematical basis. *Operations Research,* 9(3), pp. 167-179.

Kelley, J. & Walker, M., 1959. *Critical-Path planning and scheduling.* New York, USA, Proceedings of the Eastern Joint Computer Conference, pp. 160-173.

KFW Development Bank, 2015. *KFW.* [Online], Available at: www.kfw-entwicklungsbank.de, [Accessed December 2015].

KFW, 2019. *Materials on Development financing,* KFW development Bank.

Kim, J. & Ellis Jr, R., 2008. Permutation-based elitist genetic algorithm for optimization of large sized resource-constrained project scheduling. *ASCE Journal of Construction Engineering and Management,* 134(11), pp. 904-913.

Lakshminarayanan, S., Guarav, A. & Arun, C., 2010. Multi-objective optimization of time-cost-risk using Ant Colony optimization. *International Journal of Project Planning and Finance,* 1(1), pp. 22-38.

Leu, S. & Yang, C., 1999. GA-based multicriteria optimal model for construction scheduling. *Journal of Construction Engineering and Management,* 125(6), pp. 420-427.

Li, H., Cao, J. & Love, P., 1999. Using machine learning and GA to solve time-cost trade-off problems. *ASCE Journal of Construction Engineering and Management,* 125(5), pp. 347-353.

Liu, L., Burns, S. & Feng, C., 1995. Construction Time-Cost trase-off analysis using LP/IP hybrid method. *ASCE Journal of Construction Engineering and Management,* 121(4), pp. 446-454.

Liu, S. & Wang, C., 2010. Profit optimization for multiproject scheduling problems considering cash flow. *Journal of Construction Engineering and Management,* 136(12), p. 2010.

Liu, S.-S. & Wang, C.-J., 2011. Optimizing project selection and scheduling problems with time-dependent resource constraints. *Automation in Construction,* Volume 20, pp. 1110-1119.

Marler, R. T. & Arora, J. S., 2004. Survey of multi-objective optimization methods for engineering. *Journal of structural and multidisciplinary optimization,* 26(6), pp. pp 369-395.

Meyer, W. & Shaffer, L., 1963. *Extensions of the Critical path method through the application of integer programming,* Urbana, IL:

Meyer, W. & Shaffer, L., 1998. Resource Leveling of linear schedules using linteger linear programming. *ASCE Journal of Construction Engineering and Management,* 124(3), pp. 232-244.

MIGA, 2015. *The Multilateral Investment Guarantee Agency.* [Online]
Available at: www.miga.org
[Accessed December 2015].

Moder, J., Phillips, C. & Davis, E., 1983. *Project Management with CPM, PERT and Precedence Diagramming.* 3rd Edition ed. New York: Can Nostrand Reinhold Company.

Moselhi, O., 1993. Schedule compression using direct stiffness method. *Canadian Journal of Civil Engineering,* 20(1), pp. 65-72.

Moselhi, O. & El-Rayes, K., 1993. Scheduling of repetitive with cost optimization. *ASCE Journal of Construction Engineering and Management,* 119(4), pp. 681-697.

Moselhi, O. & Lorterapong, P., 1993. Least Impact Algorithm for Resource Allocation. *Canadian Journal of Civil Engineering*, 20(2), pp. 180-188.

Ng, S. & Zhang, Y., 1997. A resource scheduling decisiion support system for concurrent project management. *International Journal of Production Research*, 35(11), pp. 3107-3132.

Nkasu, M. M. & Leung, K. H., 1997. A resource scheduling decision support system for concurrent project management. *International Journal of Production Research,* 35(11), pp. 3107-3132.

OFID, 2015. *The OPEC find for International Development.* [Online], Available at: www.ofid.org, [Accessed December 2015].

Patanakul, P. & Milosevic, D., 2008-a. The effectiveness in managing a group of multiple projects: Factors of influence and measurement criteria. *International Journal of Project Management.*

Patanakul, P. & Milosevic, D., 2008-b. A competency model for effectiveness in managing multiple projects. *Journal of High technology Management Research,* Volume 18, pp. 118-131.

Perakis, R. & Savedoff, W., 2015. *Does results-based aid change anything? pecuniary interests, attention, accountability and discretion in four case studies,* Washington, DC:

Platje, A., Seidel, H. & Sipke, W., 1994. Project and Porfolio Planning Cycle. *International Journal of Project Management*, 12(2), pp. 100-106.

Robinson, D., 1975. A dynamic programming solution to cost-time trade-off for CPM. *Management Science*, 22(2), pp. 158-166.

Saadah, F., 2015. *Questions and Answers about the World Bank's Program-for-Results* [Interview] (October 2015).

Samuel, L., 2010. *Critical path method (CPM),* Columbia, SC: Health Services Policy and Management Courses. University of South Carolina.

Senouci, A. & Eldin, N., 2004. Use of genetic algorithms in resource scheduling of construction projects. *ASCE journal of construction engineering and management,* 130(6), pp. 869-877.

Shenhar, A. J. & Thamhain, H. J., 1994. A New mixture of management skills: meeting the high-technilogy managerial challenges. *Human Systems Management,* 13(1), pp. 27-40.

SIDA, 2015. *Results based financing approaches (RBFA) - what are they?,* Stockholm:

Siemens, N., 1971. A simple CPM time-cost trade-off algorithm. *Management Science,* 17(6), pp. 354-363.

Sriprasert, E. & Dawood, N., 2002. *Requirements identification for 4D constraint-based construction planning and control system.* s.l., Construction Informatics Digital Library.

Tabayang, W. & Benjaoran, V., 2015. Modified finance-based scheduling model with variable contractor-to-subcontractor payment arrangement. *KSCE Journal of Civil Engineering*, pp. 1-15.

Tamimi, S. & Diekmann, J., 1988. Soft Logic in network analysis. *ASCE Journal of Computing in Civil Engineering,* 2(3), pp. 289-300.

The World Bank Group, 2015-c. *PforR Brochure.* [Online], Available at: www.worldbank.org [Accessed February 2016].

The World Bank, 2011. *A Guide to the World Bank.* Third Edition ed. Washington, D.C.

The World Bank, 2011. *A new instrument to advance development effectiveness: Program for results financing*.

The World Bank, 2012. *Program-For-Results Financing: Interim Guidance Notes to Staff on Assessments*.

The World Bank, 2013. *Ethiopia - Health Millenium Development Goals Program-For-Results,*

The World Bank, 2013. *Financing Renewable Energy, options for developing financing instruments using public funds,* The World Bank.

The World Bank, 2014. *India - Maharashtra Rural Water Supply and Sanitation Program,*

The World Bank, 2014. *SORT Guidance Note,* The World Bank, 2015-A. *Program Appraisal Document for a Sustainable Rural Sanitation Services Program for Results,*

The World Bank, 2015-B. *Program-For-Results: Two-Year Review,* World Bank Group.

The World Bank, 2015-C. *Nigeria - The Saving One Million Lives Initiative,*

The World Bank, 2016-A. *PforR Brochure.* [Online], Available at: www.worldbank.org, [Accessed February 2016].

The World Bank, 2016-B. *Program for Results operations.* [Online], Available at: http://pubdocs.worldbank.org/pubdocs/publicdoc/2016/2/347641455287498352/PforR-chart-of-operations-2-11-16.pdf, [Accessed February 2016].

The World Bank, 2018. *PforR active portfolio,* World Bank Group.

The World Bank, 2019-A. *Program-For-Results.* [Online], Available at: https://www.worldbank.org/en/programs/program-for-results-financing, [Accessed July 2019].

The World Bank, 2019-B. *Program-For-results: proposal to remove the cap on commitment authority,* The World Bank Group.

Turner, J. R. & Speiser, A., 1992. Programme management and its information systems requirements. *International Journal of Project Management* , 10(4), pp. 196-204.

United Nations, 2003. *Monterrey consensus of the international conference on financing for development,* New York: United Nations.

USAID, 2015. *The United Stated Agency for International Development.* [Online] Available at: www.usaid.gov , [Accessed December 2015].

Zahran, K. & Ezeldin, A., 2016-a. *Funding Infrastructure Projects Through International Financial Institutions.* London, Canada, Canadian Society of Civil Engineers , pp. GEN-60-1-11.

Zahran, K. & Ezeldin, A., 2016-b. *The Application of Program-For-Results Funding Mechanism on Infrastructure Programs.* London, Canada, Canadian Society of Civil Engineers , pp. GEN-148-1-7.

Zahran, K. & Ezeldin, A., 2017-A. *Framework of a Decision Support System for Applying Program-For-Results Funding Mechanism.* Valencia, Spain, ISEC-9.

Zahran, K. & Ezeldin, A., 2017-B. *Program-For-Results: An Analysis of Procurement Strategies.* Valencia, Spain, ISEC-9, pp. PND-1: 1-6.

Zahran, K. & Ezeldin, A., 2019. *Risk Assessment of Results-Based Funding mechanisms for Infrastructure programs.* Los Angeles, CA, ASCE.

Zhang, H., Li, H. & Tam, C., 2006-b. Particle swarm optimization for resource-constrained project scheduling. *International Journal of Project Management,* 24(1), pp. 83-92.

Zhang, H., Li, H. & Tam, C., 2006. Heuristic Scheduling of resource-constrained, multiple-mode and repetitive projects. *Construction Management and Economics,* 24(2), pp. 159-169.

Zheng, X., Ng, S. & Kumaraswamy, M., 2004. Applying a genetic algorithm-based multiobjectve approach for time-cost optimization. *ASCE Journal of Construction Engineering and Management,* 130(2), pp. 168-176.

Zhou, J. et al., 2013. A review of methods and algorithms for optimizing construction scheduling. *Journal of the Operational Research Society,* Volume 64, pp. 1091-1105.